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SECOND ANNUAL REPORT

OF THE

Health

INDUSTRIAL FATIGUE RESEARCH BOARD

TO

30th SEPTEMBER, 1921

(INCLUDING ANALYSIS OF PUBLISHED WORK).

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"To suggest problems for investigation, and to advise upon schemes of research referred to them from time to time by the Medical Research Council, undertaken to promote better knowledge of the relations of hours of labour and of other conditions of employment, including methods of work, to functions of the human body, having regard both to the preservation of health among the workers and to industrial efficiency; and to advise the Council upon the best means for securing the fullest application of the results of this research work to the needs of industry."

OFFICES:

6, John Street, Adelphi, London, W.C.2.

SECOND ANNUAL REPORT
# of the
INDUSTRIAL FATIGUE RESEARCH BOARD
to
30th SEPTEMBER, 1921.

CONTENTS.

PART I.—REPORT OF THE BOARD.

PAGE.

Sec. 1. INTRODUCTION 5

Sec. 2. CONSTITUTION OF BOARD 7

Sec. 3. INVESTIGATIONS AND RESEARCHES 8

Sec. 4. ORGANISATION 11

Sec. 5. STAFF 13

Sec. 6. PUBLICATIONS 13

Sec. 7. EXTERNAL RELATIONS 13

Sec. 8. CONCLUSION 14

PART II.—ANALYSIS OF PUBLISHED WORK.

Sec. 1. SCOPE AND METHODS OF INVESTIGATION—

- Introduction 16
- Tests of Efficiency and Fatigue 18
  - A. *Variation in output* 19
  - B. *Sickness and mortality* 20
  - C. *Labour turnover* 21
  - D. *Lost time* 22
  - E. *Accidents* 23
  - F. *Other methods* 23

PART II.—ANALYSIS OF PUBLISHED WORK—*continued.*

Sec. 2. Hours of Labour, Spells, Rest-pauses, etc.— Page
Introduction 25
Relation to output 26
A. Variations in output during the day 26
Charging of blast-furnaces 27
Silk weaving 28
Shell-making 28
Metal polishing 29
Tinplate 29
Length of spell 30
Rest pauses 30
B. Variations in output during the week 31
Silk-weaving and boot-making 31
Charging of blast-furnaces 31
C. Variations in output over longer periods 32
(*a*) *Seasonal variations* 32
(*b*) *Effects of different systems of employment* 33
Tinplate 33
Iron and steel-making 34
Other Relations 35

Sec. 3. Other Conditions of Employment—
Introduction 37
Temperature 38
Humidity 39
Ventilation 40
Lighting 42
Conclusion 43

Sec. 4. Methods of Work—
Introduction 44
Vocational selection and guidance 44
Time and motion study 49
Other methods 54

Sec. 5. Miscellaneous Points—
Mechanical and technical efficiency 57
Organisation 57
Human and mechanical factors in efficiency 59

References 61

PART I.—
REPORT OF THE BOARD.

The Board beg leave to submit their Second Annual Report upon the progress of their work during the period ended 30th September, 1921.

1. Introduction.

The First Annual Report of the Board (17)* covered the period ended 31st March, 1920, and, but for unforseen circumstances, the present report would have dealt with the work carried out during the next succeeding year.

Under the conditions stated below, progress since January last has been in some directions delayed, and in March some important changes were made in the constitution of the Board and in the organisation of its work. It has been thought desirable accordingly to extend the period now to be reviewed until the end of September, so as not only to ensure the inclusion of all work that might normally have been completed by March last, but also to bring within the scope of this Report the period of transition following this reconstruction.

At the end of January, 1921, the Board received a provisional notice from the Medical Research Council that the Treasury, having regard to the financial condition of the country, and to the prevalence of unemployment and short-time employment, could not contemplate the continuation, after the 31st March, of the financial provision which had previously been made for the work of the Board, and that they requested that steps should be taken by that date to transfer any important work in hand to the independent support of industrial or other voluntary associations. This proposal, which the Board had had no previous reason to expect, appeared to them likely to have most unfortunate results, and they felt it to be their duty to make the strongest representations to the Council against the abrupt termination of any parts of their work without inquiry into their value to industrial health or economy, or, again, into the practical possibilities of voluntary support being forthcoming from industries or elsewhere at short notice at that time. The Board are glad to recognise that the steps which have been taken by the Council to ensure the continuance of their work have not only enabled them to avoid the sacrifice of many data already collected by them, but will also permit them to undertake fresh investigation, though on a more restricted scale than previously.

As is stated in their First Annual Report, the Board are fully in agreement with the view that part of the executive and financial responsibility for their work should be undertaken by industries themselves. They are, in fact, in continuance of the policy of the Board as originally constituted, already taking steps to bring about the formation of associations, constituted from groups of allied trades, to co-operate with the Board, and have great hopes of agreements being reached in the case of certain important industries.

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* For references *see* p. 61.

It would, however, be over sanguine to expect any widespread response of this kind at the present time. In the first place, existing circumstances are unfavourable for the initiation of schemes based on ideas which in this country are almost entirely new. Again, industries for the most part are not yet fully alive to the importance of the human factor in production and to the still greater part this is destined to play in the future, and until this is realised sufficiently to induce the spontaneous formation of organisations for the special study of this subject, some initial research must be undertaken by the Board alone with the object of indicating the methods to be applied and the problems suitable for future investigation. The practical value of the work must be clearly demonstrated before collaboration on the part of the industries can be hoped for.

But in research of the kind undertaken by the Board, initial progress is necessarily slow and some time must elapse before the practical bearing of the results obtained can be fully developed. The Board indeed have hitherto refrained from initiating research solely with the object of arriving at *immediate* practical results ; they have, instead, preferred to study the more fundamental issues in the belief that by so doing such practical recommendations as may hereafter be made may be on surer ground. Not, of course, that their published reports do not contain many directly practical suggestions ; these, however, are often merely incidental, and the time has not yet come when the full results of their work can be translated into practice.

Further, the difficulties of industrial research of this kind are formidable, and can only be fully realised by such as have had actual experience of it. Almost the whole of the investigations deal with a number of variables, none of which can be wholly controlled, and consistent results can only be secured by taking immediate advantage of opportunities as they offer, which under the industrial conditions of the last few years may suddenly lapse before investigation is complete.

As an example, may be quoted the variations in the hours of labour. At the time when the Board began (July, 1918), long hours were being worked in all industries concerned with the supply of war material of any kind. Shortly after the Armistice the hours of work were uniformly reduced, in most cases to a forty-eight hour week. Trade, however, was prosperous, hours were constant, and an excellent opportunity for investigation was provided, until the summer of 1920 when depression set in, short time was introduced and conditions became altogether abnormal.

This has been a serious hindrance to the progress of the Board's investigations. Any considerable change attendant on labour conditions is followed by a period of readjustment which continues for a long time before constancy and equilibrium become re-established. It is therefore only with quite special caution and circumspection that inferences can be drawn from results obtained during such a period, although they may very probably be of special value for collation with normal results obtained later on. Having regard, further, to the time involved in searching for suitable sources of information and in the preliminary trials required before reliable data can be secured, the obstacles in the way of rapid progress encountered since the work of the Board began will be seen to have been substantial.

2. Constitution of the Board.

During the year ended 31st March, 1921, several changes occurred in the constitution of the late Board. In June, 1920, Dr. Edward Hopkinson, M.P., to whom the Board are indebted for much valuable guidance during the early stages of their existence, felt it incumbent upon him to resign his membership owing to continued ill-health.

In October, 1920, Sir Walter Fletcher withdrew from the Board on account of pressure of other work, and Dr. Major Greenwood, Medical Officer of the Ministry of Health, was appointed in his stead.

With a view to strengthening the representation of engineering on the Board, Sir Joseph Petavel, K.B.E., D.Sc., F.R.S., Director of the National Physical Laboratory, and Mr. A. P. M. Fleming, C.B.E., M.Sc. (Tech.), Manager of the Research and Education Departments, Messrs. Metropolitan-Vickers Electrical Company, Limited, were appointed additional members. Further, Mr. T. McKerrell and Miss I. H. Sloan were nominated by the Ministry of Labour as Assessors in the place of Mr. Bertram Wilson, whose death was referred to in the First Annual Report of the Board.

The re-constitution of the Board on April 1st involved several further changes. Sir Charles Sherrington, G.B.E., P.R.S., who had acted as Chairman of the Board since its inception, resigned this position on account of the pressure of work arising from his election as President of the Royal Society, but the Board are very glad to realise that in his consenting to remain with them as a Member, the active interest he has always shown in their work will not cease, and that they will still have the benefit of his advice and guidance.

At the same time Professor E. L. Collis, Professor Winifred Cullis, Dr. Major Greenwood, and Dr. C. S. Myers, left the Board itself to join one or more of the scientific committees to be mentioned below, from which their knowledge and experience continues to be of direct service to the Board.

Mr. A. P. M. Fleming, Mr. Kenneth Lee and Dr. T. M. Legge, who also withdrew from the Board owing to the exigencies of other duties, have continued to collaborate in the work, and the

Board are indebted to them for much valuable assistance since their formal connexion ceased.

In order to secure closer touch with the Medical Research Council, two members of the Council were appointed to the Board, Mr. William Graham, M.P., as Chairman in place of Sir Charles Sherrington, and Mr. C. J. Bond as member. At the same time Professor E. H. Starling, F.R.S., was appointed a member.

It should be stated that the Board as constituted before the 1st April last were responsible for the initiation and supervision of nearly the whole of the work referred to in the present report.

3. Investigation and Researches.

The general scheme of work has followed almost exactly the course already described in the First Annual Report. Roughly, the Board's investigation has proceeded on two parallel lines: (1) general inquiry into the conditions of certain industries; and (2) research on special subjects. The former have been conducted entirely by the Board's investigating staff, whilst the latter has been in several instances carried out by external workers under research grants from the Board.

In the Board's First Annual Report [**17, 13**], a full account was given of the investigations in progress on the 31st March, 1920, and of the lines on which they were proceeding.

The following have now been completed, although in some instances the results are not yet available :—

(1) *Iron and Steel Industry.*—The results of the investigation, which was conducted by Dr. H. M. Vernon, have now been published. [**5**].

(2) *Cotton Industry.*—The collection of data for the main investigation dealing with weaving was completed on the 31st December last, and Mr. S. Wyatt, M.Sc., assisted by Mr. A. D. Ogden, is now engaged on their co-ordination. Owing to the large volume accumulated, some time must elapse before a final report can be submitted. Meantime, two reports embodying the results of side inquiries have been published. [**7,** and **8**]. The results of a supplementary inquiry by Mr. H. C. Weston into the kindred process of linen-weaving are now being embodied in a report.

(3) *Silk Industry.*—The results of this investigation, conducted by Mr. P. M. Elton, M.Sc., have now been published. [**9**]. A further report by Mr. Elton, generously placed at the disposal of the Board by Messrs. Grout & Company, Limited, of Great Yarmouth, is now under consideration.

(4) *Boot and Shoe Industry.*—Professor Thomas Loveday, who was originally in charge of the investigation, was compelled to relinquish the work in May, 1920, on being appointed Principal of the University College of Southampton. Since then the inquiry has been continued under the control of Professor E. L. Collis with the assistance of Mr. T. Bedford and Mr. J. Loveday, M.A. The collection of data is now complete and a final report

is in course of preparation. During the last year, two interim reports dealing with this industry were published by the Board. [**10** ; **11**].

(5) *Laundry Industry.*—The collection of data is now complete, and Miss May Smith (who until recently was assisted by Mrs. C. Carlile, Miss B. F. McFie, and Miss P. M. Vickers), is engaged in the preparation of a report.

(6) *Statistical Investigation.*—The estimation of labour turnover in munition making, etc. (based largely upon employment records at the Ministry of Munitions) which, on the retirement of Miss G. M. Broughton to take up an appointment in India, was continued by Miss E. M. Newbold and Miss E. C. Allen, has now been completed, and the report embodying the results published. [**13**].

(7) *Vocational Selection.*—A review of the literature on this subject, compiled by Mr. B. Muscio, M.A., has been published. [**12**]. Three studies in vocational selection entitled respectively :—

(*a*) " The Psycho-physiological Capacities required by the Hand Compositor ; "

(*b*) " The Measurement of Physical Strength with Reference to Vocational Guidance ; "

(*c*) " Physical Measurements in a Confectionery Factory ; "

have also been issued under a single cover. [**16.**]

(8) *Time and Motion Study.*—A report by Mr. E. Farmer, M.A., summarising the work already carried out on this subject, and containing a complete bibliography, has been published. [**14**]. In addition, research on this subject has been undertaken by Mr. Farmer (assisted by Mr. A. S. Brooke, M.C., M.A. and Mr. C. Carlile, B.A.), in two factories (Messrs. Pascall & Sons, Limited, Confectionery Manufacturers, London, and the Sheffield Flatware Company, Limited, Cutlery Manufacturers, Sheffield), and the results have been recently published. [**14 ; 15**].

The main investigations now in progress or under consideration are as follows :—

(9) *Pottery Industry.*—Hitherto this investigation, which has been entrusted to Dr. Vernon (assisted by Mr. T. Bedford), has dealt principally with the conditions of employment in the drying rooms of potteries. The Board originally hoped that the inquiry might be a joint one, to be carried out by Dr. Vernon and a technical expert in pottery processes nominated by the industry. The realisation of the scheme was, however, found to be impracticable, and, as an alternative, an arrangement was made whereby Dr. Vernon should be able to obtain assistance on technical points from a Sub-Committee formed of the Panel Members to the Committee.

(10) *Flax and Hemp Industries and* (11) *Jute Industries.*—Application has been received from their respective Trade Boards for the Board to undertake investigations into the effect on fatigue and efficiency of the different hours of employment now in force. The investigations were duly approved by the late Board, but

were subsequently deferred owing to the introduction of short time in the textile trade.

(12) *Glass Industry.*—A request for the collaboration of the Board has been received from the Research Association for the Glass Industry and is now under consideration.

(13) *Iron Foundries.*—The National Union of Foundry Workers have approached the Board with a request for investigation into foundry conditions.

(14) *Post Office Work.*—By arrangement with the Post Office the Board have now under consideration the possibility of making inquiry on the following points :—

(*a*) At offices where it is impossible to arrange continuous 8-hour duties for all the staff, is it preferable to split the duties into two halves, or to arrange long and short continuous duties on alternative days ? Where split duties are worked, what is the ideal interval between the two halves from the point of view of industrial fatigue ?

(*b*) Are changes of work within a spell of duty in telegraph offices (either to similar work or to different work) beneficial to the individual or otherwise ?

(*c*) Can any means be suggested to minimising or preventing the liability to telegraphists' cramp (Morse or Baudot) ?

(*d*) Is it desirable that the training of telegraphists should be intensive, or that it should be spread over a fairly long period, with intervals of non-manipulative work ?

(15) *Statistical Investigation.*—As explained in the analysis attached to this Report (p. 20), the Board have usually endeavoured to support the reports on their industrial investigations by data relating to sickness and mortality in the trades concerned. Such data collected by Mr. E. A. Rusher and Dr. H. M. Vernon for the iron and steel industry have now been published. [**5.**] Similar inquiries are now in progress in the boot and shoe and foundry industries.

(16) *Physiological Research.*—The following have received financial support from the Board during the past year :—

Research on effects of work on pulse variations and wink reflex (conducted by Dr. B. A. McSwiney, M.B., and Mr. W. D. Hambly, B.Sc.).

Research on respiratory metabolism (conducted by Dr. A. D. Waller and Miss G. de Decker).

Research on estimation of respiratory quotient in women (conducted by Professor Winifred Cullis, D.Sc.).

(17) *Psychological Research.*—The main lines on which this is proceeding under the control of Mr. Muscio (assisted by Miss S. C. H. Sowton and Miss H. Sturt) is as follows :—

(*a*) Determination of the qualities required for typewriting.

(*b*) Determination of the question whether it is better to emphasize speed or accuracy in learning skilled work.

(*c*) Determination of effect of rate of movement upon accuracy with reference to the explanation of accident curves.

(*d*) Determination of the interrelation of different motor capacities with reference to the problem of selecting those possessed of special dexterity for occupations requiring it.

4. Organisation.

The general machinery for the supervision of the industrial side of the investigations has remained practically unaltered. The Committees set up for this purpose (the constitution of which will be found in the First Annual Report) have all continued to help the Board with technical advice, and the thanks of the Board are again due to the Panel Members representing the trades concerned for their assistance throughout.*

An important step, intended to secure adequate scientific supervision of research and criticism of the Board's work was taken early in the present year. This consisted in the formation of special scientific Committees to advise upon and to supervise the conduct of particular parts of the work of the Board. Under the scheme of re-organisation this system was continued in essentially the same form through the appointment by the Medical Research Council of four expert Committees. These Committees have already made valuable critical and constructive proposals for the furtherance of the work of the Board.

COMMITTEE ON INDUSTRIAL HEALTH STATISTICS.

Major Greenwood, M.R.C.P. (Medical Officer of the Ministry of Health). (*Chairman*).
John Brownlee, M.D., D.Sc. (Director of Statistics, Medical Research Council).
E. L. Collis, M.D., M.R.C.P. (Talbot Professor of Preventive Medicine, Cardiff).
A. Henry, F.I.A. (Deputy Government Actuary).
L. Isserlis, M.A., D.Sc. (Statistician to the United Kingdom Chamber of Shipping).
G. Udny Yule, C.B.E., M.A., F.R.S. (University Lecturer in Statistics, Cambridge).
Miss E. C. Allen. (*Secretary*).

The Committee has been largely engaged in the critical examination of reports submitted by the Board's investigators. In addition, the inquiries into sickness and mortality in the boot and shoe and foundry industries (pp. 8, 10) are being continued under their supervision by Mr. E. A. Rusher, F.I.A. while Miss E. Newbold, M.A., and Miss E. C. Allen are engaged in the statistical treatment of the data collected by Mr. Wyatt in the investigation into the cotton industry (p. 8).

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* In addition to the Committees mentioned in the First Annual Report the following has been formed to supervise the investigation in the Potteries Industry:—Dr. T. M. Legge, C.B.E. (*Chairman*), Professor E. L. Collis, M.D., Professor Winifred Cullis, D.Sc., Miss Mona Wilson, J.P. *Panel Members:* Mr. Joseph Burton, Mr. S. Clowes, J.P., Mr. A. Hollins, Mr. A. H. Maddock. *Assessor:* Mr. E. A. R. Werner, O.B.E., H. M. Superintending Inspector of Factories.

Committee on the Physiology of Muscular Work.

E. H. Starling, C.M.G., F.R.S. (Professor of Physiology, University of London). (*Chairman*).

F. A. Bainbridge, M.D., F.R.S. (Professor of Physiology, St. Bartholomew's Hospital).

E. P. Cathcart, M.D., F.R.S. (Professor of Physiology, Glasgow University).

A. V. Hill, Sc.D., F.R.S. (Professor of Physiology, University of Manchester).

B. A. McSwiney, M.B. (*Secretary*).

Research has been initiated on certain problems connected with heavy labour.

In particular, Mr. H. Lupton, B.Sc., is engaged under Professor A. V. Hill in investigating the rate of recovery after muscular exercise, with a view to elucidating the optimum arrangement of hours for work of different kinds, and Mr. G. McCullum under Professor E. P. Cathcart on a somewhat similar investigation with special reference to women.

The Board have to record with deep regret the death of Professor F. A. Bainbridge, who showed an active interest in the work of this Committee and had consented to undertake responsibility for research on the measurement of muscular efficiency and fatigue. Arrangements are now being made for this side of the work to be carried out under the control of Dr. M. S. Pembrey.

Committee on Physiology of the Respiratory and the Cardio-Vascular Systems.

Leonard Hill, M.B., F.R.S. (Director of Applied Physiology, National Institute for Medical Research). (*Chairman*).

J. C. Bridge, F.R.C.S., Ed. (H. M. Medical Inspector of Factories).

Winifred Cullis, D.Sc. (Professor of Physiology, University of London).

Wing-Commander Martin Flack, C.B.E., M.B. (Director of Medical Research, Royal Air Force).

Sir Thomas Lewis, C.B.E., M.D., F.R.S. (Lecturer in Cardiac Pathology, University College Hospital, London).

The Committee has been principally engaged in examination of numerous outstanding reports dealing with industrial investigations, and in particular with the effects of fatigue and efficiency of the worker's environment.

COMMITTEE ON PSYCHOLOGY.

Henry Head, M.D., F.R.S. (Member of the Medical Research Council). (*Chairman*).

Cyril Burt, M.A. (Psychologist to the London County Council).

T. H. Pear, M.A. (Professor of Psychology, University of Manchester).

W. H. R. Rivers, M.D., F.R.S. (Lecturer on Physiological and Experimental Psychology, University of Cambridge).

Sir Charles Sherrington, G.B.E., Sc.D., P.R.S. (Professor of Physiology, University of Oxford).

The Committee has reported favourably on the psychological work carried out by the Board, as embodied in the reports submitted by Mr. Muscio and Mr. Farmer.

With the approval of the Council, research will be undertaken by Miss S. C. M. Sowton under the supervision of Dr. C. S. Myers on the psychological effects of the menstrual period.

5. Staff.

The names of the Investigators engaged in the different inquiries completed or in progress have been already given in Section 3. The Board desire to record their high appreciation of the ability with which the Investigating Staff have carried out their difficult and exacting work.

The Board have to announce the resignation as from January next of Mr. B. Muscio, M.A., on his election to the Challis Chair of Philosophy, University of Sydney. Mr. Muscio, who has been engaged with the Board since March, 1919, has carried out most valuable original work, and the loss of his assistance in the future will be greatly felt by them.

6. Publications.

Sixteen reports have now been published (in addition to papers contributed by the investigating staff to scientific journals). A full list with summaries of each report appears on page 61, and an analysis of their contents will be found in Part II.

7. External Relations.

Close relations have continued with the American, Canadian and French Committees established with aims similar to those of the Board.

Arrangements have also been made with the National Institute of Industrial Psychology for complete co-operation including the free interchange of investigators.

The Departmental Committee on Factory Lighting, which has been reappointed by the Home Office, has as Secretary, one of the investigators to the Board, and has invited the assistance of the Board in the investigation of certain matters within their sphere.

As stated in the Board's First Annual Report, Dr. C. S. Myers and Miss Mona Wilson visited certain factories in which some form of scientific management had been adopted, in order to apprise the Board of the attitude of Trade Unions and workmen generally towards these methods. A report, covering a period ended in December last, has been received, and the Board propose at an early date to discuss the points raised in it at a special conference with prominent Trade Union officials.

The Board wish to ackowledge the assistance and advice received from the Home Office, the Ministry of Health, and the Ministry of Labour. In particular, they are indebted to the Chief Inspector of Factories and his staff for much valuable guidance in securing facilities for investigation.

The Board have again to record the invaluable help received from the employers and workmen with whom they have been in touch, without which progress in the industrial side of their work would have been impossible.

8. Conclusion.

A short description has already been given of the investigations in progress, and a more complete account of the work already accomplished will be found in Part II of the present Report. The Board venture to hope that this work will be accepted as a substantial contribution towards the elucidation of the principles governing the healthy employment of the human mind and body in industry, the need for which in this country was alluded to in their First Annual Report, and that it will enable some at least of the problems with which industries have been always confronted, to be studied on a definite basis of fact.

As the work of the Board proceeds, however, new fields of investigation are continually opening out, which lie beyond both the scope and the present resources of the Board. If these are to be adequately explored, the Board think it essential that the industries should extend their co-operation with the Board, by agreeing themselves to assume partial responsibility for the supervision and the financial support of the industrial side of their work.

The Board are unwilling at the present stage to formulate any detailed schemes dealing with the method and extent of co-operation. They suggest, however, that for the successful development of the work on the industrial side due regard must be had to the following considerations.

First, the Board are disposed to think that industries themselves should have a full and even predominant share in the supervision of such investigations, and in deciding upon the problems to be studied. As already stated, the Board are concerned primarily with the acquisition of scientific knowledge ; in the practical application of such knowledge, industries are the best judges of their own needs.

Secondly, the Board regard it as important that responsibility for initiation and prosecution of the work should be shared so far as possible, equally between employer's and workmen's representatives, acting together.

Lastly, the Board feel that, in general distinction from technical and material industrial research, problems arising in their work have often a common interest to more than one particular industry, so that economy, as well as greater opportunities, might be secured by adopting a wider unit of grouping, and by co-operation with *groups* of industries having certain features in common rather than with each such industry separately.

In conclusion, the Board desire to record their high appreciation of the services rendered by their Secretary, Mr. D. R. Wilson, who has acted as Secretary from the beginning. During the period of reconstruction which has elapsed since the Board was re-constituted the many additional burdens of maintaining, so far as was possible, the organisation previously existing, of considering the problems of re-organisation and of securing the continuance of investigations in progress, have fallen on his shoulders, and it is due to his energy and ability that the maintenance of the work on a satisfactory basis has been so readily affected. It is through him that the Board are enabled to present the following analysis, which is necessarily mainly his work, of the investigations hitherto undertaken for the Board.

PART II.—
ANALYSIS OF PUBLISHED WORK.

SECTION 1. SCOPE AND METHODS OF INVESTIGATION.

Introduction.

In the following analysis an attempt is made to present in simple form and on a systematic plan the principal facts contained in the published reports of the Board. The most convenient arrangement has seemed to be to adopt, so far as possible, a system suggested by the original terms of reference to the Board, which run as follows :—

> To consider and investigate the relations of the hours of labour and of other conditions of employment, including methods of work, to the production of fatigue, having regard both to industrial efficiency and to the preservation of health among the workers.

It will be noted that conditions arising outside the place of work (e.g., food, transport, housing) are implicitly excluded.

The principal points brought out in the report have accordingly been collated and combined into three groups, according to whether they relate to the effects on fatigue and efficiency of :—

(*a*) *Hours of labour,* including spells, rest pauses, etc.;
(*b*) *Other conditions of employment,* or the physical conditions of the worker's environment, constituting the *impersonal* factors in efficiency and fatigue ;
(*c*) *Methods of work,* constituting the *personal* factors in efficiency and fatigue.

At the time when the Board started their work (July, 1918), hours of labour were very long, and the fatigue produced was often of the gross kind which corresponds to the popular interpretation of the word and borders on the pathological sphere. With the almost universal shortening of hours early in 1919, this class of fatigue largely disappeared, and the word was thenceforward accepted rather in the technical sense of its definition, viz., *the sum of the results of activity which show themselves in a diminished capacity for work* [**25,** 15].*

To assert, however, that fatigue no longer exists would be wrong. The real difference is that it is now for the most part normal, and consistent with complete recovery on rest, and therefore with health. The work of the Board has been mainly devoted to the study of principles governing the onset and reduction of this class of fatigue with a view to increasing the *efficiency of the human factor* in industry.* Such practical matters as optimum hours of work and length of spell, frequency of rest-pauses, effects of overtime, etc.; all have a direct bearing on fatigue, and indeed can only be satisfactorily studied through the direct or indirect estimation of the fatigue produced.

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* Throughout this report the *thick* figures correspond with the references given on p. 61, the *ordinary* figures with the page of the reference in question.

The investigations hitherto carried out have in the present state of knowledge been necessarily almost wholly *comparative* in character, that is to say, their object has been to discover which of two sets of similar conditions is the more favourable by applying a suitable test successively to each. For example, shifts of different lengths, the seasons of the year, the use of natural and artificial light, have all been compared in terms of output, different occupations in an industry in terms of sickness incidence, different factories of the same type in terms of the "labour turnover" experienced.

Human efficiency and fatigue, however, are dependent on the joint effects of a large number of conditions. In field investigation it is clearly impracticable to isolate any one set of conditions for special study, and as a rule, therefore, the Board have had to deal with the relation of fatigue and efficiency to each of two or more possible variables functioning simultaneously, one consisting of different hours of labour, the other of the several other conditions of employment. For the complete study of this problem it is theoretically necessary to have at disposal :—

(1) sufficiently long periods of uniform hours of work ;
(2) methods of estimating separately the effects of "other conditions of employment ;" and
(3) methods of eliminating the effect of any conditions not due to employment, which may influence the onset of fatigue ;

together with some means of measuring or estimating the fatigue produced.

In practice, the procedure can sometimes be greatly simplified by keeping, during the study of any one of these variables, the others so far as possible constant. During normal industrial activity, hours of labour may usually be regarded as a constant, though even here it is essential that a *long* period of uniform hours must be available owing to the delay occurring before equilibrium is established after a change of hours takes place [**6**]. By the conversion of one variable into a constant the study of the effect of the others becomes a far easier task.

As an example of this method of procedure the investigation into cotton weaving now in progress may be quoted. This is based chiefly on hourly records of output taken on a large number of looms for a period of one year. By arrangement with the employers concerned the looms were devoted throughout the investigation to the weaving of a standard cloth of uniform quality, thus approximating to constancy from the manufacturing point of view ; further, the hours of employment during the first nine months of the experiment were normal and uniform, though thereafter they were shortened in common with most other trades. Hence, since both hours of work and manufacturing conditions have remained constant for a considerable period, there has been an opportunity of directly estimating the effects of "other conditions," such as temperature, humidity and lighting.* Conversely, by selecting periods when " other conditions " were constant, the effects of hours of labour may be estimated.

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* The word "*efficiency*" here and elsewhere in this report is not to be interpreted as equivalent merely to productive efficiency, but as the physiological quality which results from favourable conditions of work. The word is in fact almost equivalent to "*fitness.*"

The conditions of living outside the factory, being excluded from the Board's reference, have not been studied, though occasional references to them occur, for instance, in respect of " causes of lost time in silk weaving " [**9**, 17] and of the " effect of civil state on rate of leaving " [**13,** 17]. They probably exert a smaller influence now than during the war, when conditions of housing, transport and food were to a large extent abnormal, and in the reports published by the Board which are based on " mass " data, the law of averages has been assumed to apply and the data to represent, on the whole, real conditions. In the study of individuals it is obviously desirable that this factor should be taken into account, and the necessary information on this point is always so far as possible obtained.

Tests of Efficiency and Fatigue.

For the measurement of the fatigue produced no satisfactory direct test has yet been evolved. In this side of the Board's work, two chief difficulties have been experienced. The first is that any test of fatigue depends on the measurement of a capacity rather than of an achievement. Careful distinction must, for instance, be made between a test for fatigue and a mere measure of the work done or energy expended. The latter may be of value in other respects (e.g., in estimating the arduousness of different kinds of work† in cases where mechanical computation is difficult or impossible), but a direct and immediate test of fatigue is a far more subtle problem, which has so far eluded discovery. The second difficulty is that of completely eliminating volition, the exercise of which may entirely invalidate results obtained from many tests [**19**]. For this reason the phenomena selected for preliminary study have for the most part been those which are almost independent of the will of the subject.*

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* In the particular case of cotton weaving, a further complication arises from the fact that these conditions of employment themselves have a marked effect on the process of manufacture.

† For an account of an ingenious method designed by Frois for measuring the energy expended in riveting see [**22**].

In the absence of a direct test the Board have had to rely upon indirect methods of estimating or indicating fatigue. The following may be regarded as standard methods, viz. :—

(*a*) Variations in output and other performance tests ;
(*b*) Sickness and mortality ;
(*c*) Labour turnover ;
(*d*) Lost time ;
(*e*) Accidents ;

though others have been adopted occasionally to meet special circumstances.

A.—VARIATIONS IN OUTPUT.

Variation in output is the most generally used and is probably the most trustworthy, provided that adequate allowance can be made for certain disturbing factors, such as incentive or technical improvement. Strictly speaking, however, variations in output measure variations in performance and not in capacity to perform ; there is, for instance, no reason why the reduction in output (which in the absence of other causes is assumed to be due to fatigue) should not at any point where the measurements cease have been succeeded by an increase in output.† Nevertheless, where under two systems of employment the rate of output per man is uniformly different [**1,** 6 ; **5,** 13], or where the hours or spells of work are such that there is a uniform reduction as time progresses [**2,** 10 ; **9,** 29], it has been assumed that such effects (in the absence of other explanation) may be justifiably ascribed to the fatigue induced.

The advantage of using output as a test is that it can be applied either by the collection of current data or by the examination of existing records, and both methods have been adopted by the Board, the former in tinplate [**1,** 9], shell-making [**2**], silk-weaving [**9**], and metal polishing [**15**], the latter in tinplate [**1,** 6], iron and steel manufacture [**5**], and boot and shoe manufacture [**10,** 16, 28].

There are, however, two limitations to its use as a universal test for fatigue. First, it can only be applied to processes which lend themselves to measurement of output in terms of units, which are either constant over a sufficiently long period or are capable of being rendered constant by calculation. In only a few of the investigations carried out by the Board (as in shell-making [**2**] and in the investigation into cotton-weaving now in progress) has it been found possible to adhere throughout to a uniform unit. Recourse has generally therefore been had to calculation. The precise formula used in any particular case must be adapted to the special circumstances, and several examples occur in the reports of the Board (in particular in the case of tinplate [**1,** 13], steel-making [**5,** 30], silk-weaving [**9,** 12], and metal polishing [**15,** 12]), to which reference may be made for further details.

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* Some research on this point has been undertaken, in particular on the possibility of devising tests based on (*a*) variation in pulse rate depression ; (*b*) wink reflex ; (*c*) respiratory metabolism [**20**] ; and some preliminary experiments have been carried out with Ryan's Vascular Skin Reaction Test and Martin's Muscular Strength Test [**16**].

† For a discussion of the different factors in fatigue see [**19**] and [**19a**].

Secondly, the sensitiveness as a test of this method depends on the nature of the work, and, in particular, on the extent to which the human factor plays a part in production [**7**]. This varies from 100 per cent. in completely manual processes to almost 0 per cent. in completely automatic processes. For the latter kind of process variation in output is obviously unsuitable as a test, and another test must be found before fatigue can be adequately studied.

In addition to *quantity* of output, the *quality* of output, as measured by the amount of spoiled work, would probably be a useful indication of fatigue in special cases, e.g., in repetitive processes on small articles. Up to the present, however, no opportunity of applying this method has occurred, though a modification of it has been used by Vernon (see p. 23).

Finally, research has been conducted by Muscio [**18**] and Wyatt and Weston [**21**] into the possibility of using the performance of certain set tasks under special conditions as a measure of fatigue.

B.—Sickness and Mortality.

As already pointed out the industrial fatigue now existing is normal rather than pathological, and its relation to health is therefore less accentuated than it was at the time when the Board was started. The Board have, however, sometimes endeavoured to supplement their main industrial inquiries with collateral investigations into sickness incidence and mortality in the industries concerned. The justification for this course may be expressed in three ways :—

(i) Unfavourable physiological conditions, if inherent in a given occupation, may sometimes be reflected in the high rate of sickness and mortality for that occupation as compared with the industry generally.

(ii) In industries involving exceptionally arduous work or subject to exceptional conditions of employment, study of morbidity and mortality may denote whether excessive fatigue due to such work or conditions actually exists, and if so, in which particular occupations.

(iii) An abnormally high rate of sickness or mortality found in a given industry may, in the absence of any other explanation, be *prima facie,* an indication that such industry will offer a fruitful field for investigation.

Cotton weaving may be quoted as an example of the first type of inquiry. For many years there has been serious complaint on the part of the operatives concerning the artificial introduction of steam into sheds in which certain classes of material are made. A statistical investigation into the sickness incidence in the trade, of such a kind as will admit of comparison between sheds which are artificially humidified and sheds which are not, was approved by the Board, in the expectation that light would be thrown on the effects of the conditions of employment. The investigation has not yet started owing to the present abnormal condition of the industry.

The second type of inquiry is exemplified by an investigation into the sickness incidence and mortality amongst workers in the iron and steel trades carried out by Rusher and Vernon, the results of which have been published in the main report on the industrial inquiry [**5,** 78]. Though based on data which are only roughly comparable amongst themselves, they show clearly that some occupations are more harmful than others. For instance, men on the heaviest work experienced the most sickness, the steel-melters and pitmen showing 23 per cent. more than the average of all workers in the industry, the puddlers 20 per cent. more, the tinplate millmen 12 per cent. more, and the rolling millmen 8 per cent. more. The engine and cranemen and the other workers (largely labourers) who usually work at ordinary temperatures and on less heavy work showed 8 or 9 per cent. less sickness than the average. The excess of sickness shown by the puddlers was due entirely to rheumatism and respiratory diseases. Rusher and Vernon think that this may be due to the special conditions of their employment, namely, the custom of alternating periods of heavy work with periods of rest or of light work, since the tinplate millmen, who work almost continuously, showed no excess of sickness from these causes. Examination of mortality records tended to confirm these conclusions, steel-melters showing 26 per cent. greater mortality than the average.

As an example of the third type, an investigation has been begun into the records of certain Approved Societies in the foundry industry, in order to ascertain whether there is abnormally heavy incidence due to any cause attributable to the nature of the work or conditions of employment, with a view to starting a more special investigation later.

C.—LABOUR TURNOVER.

Just as the bodily health of an industry is reflected in the magnitude of its sickness incidence, so is the "industrial health" of a factory reflected in the variations of certain phenomena, the study of which accordingly has a special practical bearing on fatigue and efficiency.

The first of these is *labour turnover,** or the rate of change in the working staff, which may be used (with certain limitations) as a gauge or indicator of the internal conditions of a factory. A continuously high rate occurring in one department as compared with the factory generally may, for instance, be due to causes such as fatigue or ill-health produced by the work, unsatisfactory hygienic conditions or faulty selection of workers for a particular task; an abrupt rise in the rate may indicate the introduction of a piece-rate which is regarded as unjust, or the appointment of an unpopular departmental manager or foreman. Which of the several possible reasons is the determining factor must, of course, be made the matter of special inquiry; estimation of labour turnover in itself can only indicate the need for such inquiry.

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* For a full account of the methods of investigating labour turnover, see [**22,** 360].

Broughton, Newbold and Allen [**13**], following methods devised by Greenwood [**24; 26,** 163] have calculated the labour turnover in a number of factories, partly through the employment records accumulated by the Ministry of Munitions during the war, and partly through current data kept by the factories themselves. Although the period covered by the records is too short to enable the report itself to be anything but suggestive, certain definite conclusions are indicated. Thus, individual factories differ markedly in their labour turnover, both in regard to totals and under the different reasons for leaving, but as most of the records relate to past conditions the actual causes for these differences cannot usually be traced. A characteristic feature of all the tables is the high rate of loss during the early months of service, emphasising the scope for vocational tests to discover the aptitudes of applicants for employment. If this wastage could be prevented or reduced, a serious loss of efficiency would be avoided, since the time involved both in teaching and in learning an operation is obviously so much the more profitably spent the longer a worker continues at his task after he has acquired his maximum skill. A very large loss from possibly avoidable causes, such as ill-health, incompetence, and dissatisfaction, is also indicated in the tables.

It is important to notice that whilst in gross instances a high labour turnover may be apparent without recourse to special methods, slight but continuous loss involving serious reduction in efficiency may sometimes remain entirely undetected. A reliable and sensitive means of estimating labour turnover is accordingly given in the report, together with specimens of the actual forms of record required.

D.—Lost Time.

A second test of the " health " of an industrial organisation is the time lost on the part of the workers. Lost time was investigated by Loveday [**25,** 41] and Vernon [**25,** 34; **6,** 30] for Health of Munition Workers' Committee, in the expectation that it would throw light on the prevalence of fatigue during the war.

In the Boards' reports suggestions occur for its statistical treatment and an account is given of the uses to which the results may be put [**13,** 82; **9,** 16], but it has not been extensively studied by the Board, partly because it is not a suitable measure of the normal fatigue which for the most part exists to-day, partly on account of the vagueness of description in existing records of the causes of lost time [**13,** 22], and partly on account of the upsetting effect of conditions outside employment and even of ingrained habit, which would tend to invalidate all deductions drawn [**9,** 17].* Vernon [**5,** 20], however, has used this method in the absence of others to investigate the effects of reducing shifts from 12 to 8 hours in work on blast furnaces, and has shown that the reduction in hours would probably lead to an improvement in time-keeping and to increased efficiency in the running of the furnaces.

E.—ACCIDENTS.

A clear relation exists between human efficiency and accident incidence, since the incurring of any accident involves lessened capacity, even though it may be so trivial as not to cause absence from work [**27,** 31]. The requirements of the Factory Acts are framed primarily to prevent the more serious accidents, and there remains a wide scope for investigation into the conditions which tend to produce the slighter and more numerous kind.

Greenwood and Woods [**3**], by the statistical treatment of accident records kept by certain munition factories, have adduced evidence to show that accident incidence is not wholly a matter of chance but depends largely on some quality of susceptibility inherent in the personality of the victims. The further study of this important question is now under consideration.

F.—OTHER METHODS.

In addition to these standard methods of investigation, others have been adopted to meet special conditions.

Rest Pauses.—Vernon [**1,** 9] and Farmer [**15,** 13] have both used the number and duration of rest pauses voluntarily taken to compare the effects of different conditions, in the former case shifts of different lengths (p. 35), in the latter sitting and standing work (p. 56).

Variations in Technical Conditions.—Vernon [**5,** 48] has adopted a modification of the *spoiled work* method (p. 20) in studying the fatigue of gas producer men on steel furnaces. He determined by analysis the variations in the proportions of carbon dioxide in the gas, on the assumption that fatigue would result in some decrease in attention, and that the gas would deteriorate in the quality aimed at. In actual practice, the only noticeable variation occurred when the shifts changed over and no indication of fatigue was noticeable.

Another special test of the same kind was used by Vernon [**5,** 9] in the case of mechanically charged blast furnaces. It consisted in the periodical measurement of the depth of the contents of the furnace, on the assumption that fatigue on the part of the workers would be reflected in the depth. No definite features, however, were traceable in the results.

Character of Effort involved.—Farmer [**15,** 45] has investigated the presence of fatigue in metal polishing by means of a recording watt meter attached to an electrically driven *roughing* machine. The thrusting of the article against the wheel results in a frictional retardation of the wheel, and the amount of energy required by the motor to overcome this friction is accurately recorded on the chart together with the number, duration, and pressure of each stroke. Owing to the difficulty of interpreting a chart recording each movement, no attempt was made to obtain a continuous record of the whole day's work, and the experiment was confined to getting complete records of the roughing of four spoons at eight intervals distributed throughout the day.

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* A full discussion of lost time and its causation is given by Vernon elsewhere. [**32,** 141].

The inferences drawn from the detailed study of two workers are as follows :—

(i) the time required to perform the task always increases towards the end of the day ;

(ii) whilst the *number* of strokes remain approximately constant, their *pressure* and *duration* show a marked tendency to increase, in that greater effort is expended as fatigue increases ;

(iii) the degree of fatigue developed depends largely on the methods of work adopted, being much less in the case of the steadier and more systematic worker.

SECTION 2.—HOURS OF LABOUR, SPELLS, REST PAUSES, ETC.

Introduction.

A short account of the previous work carried out in this country on the relation of hours of work to fatigue is given in the First Annual Report of the Board [**17,** 5]. In particular, the false economy of hours of work above a certain length was then clearly demonstrated by Vernon [**25,** 17] (working for the Health of Munition Workers' Committee), who showed that the long periods of employment introduced ostensibly to bring about increased production resulted in many processes in such a reduction in hourly output, as more than to counterbalance the additional time available for production, so that the *total* production was actually less than when the hours of work were subsequently reduced. This effect was found to vary in degree according to the nature of the process, and to be most marked in the case of heavy labour in which the human factor played a large part in comparison with the mechanical factor. Similarly, lost time and sickness were found in many cases to vary with the hours of labour. For details the original memorandum must be consulted (some of the main features of the investigation will be found in [**6**]), but the following table shows the general results obtained :—

TABLE I.—*Relation of Hours of Work to Production.**

Process.	Statistical Period (weeks).	Average hours of Work.		Average Hourly Output.	Total Output (hours × hourly output).
		Nominal.	Actual.		
	A.	*Heavy Labour.*			
27 to 90 men sizing fuse bodies.	6	66·7	58·2	100	5820 (=100)
	20	60·2	51·0	120	6120 (=105)
	11	55·5	50·4	137	6905 (=119)
	B.	*Moderately Heavy Labour.*			
70 to 100 women turning aluminium fuse bodies.	10	74·5	66·0	108	7128 (=100)
	16	63·5	54·4	131	7126 (=100)
	24	55·3	47·5	169	8028 (=113)
	C.	*Light Labour.*			
17 youths boring top caps.	11	76·6	70·6	105	7413 (=100)
	46	60·1	54·5	127	6922 (= 93)

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* In this table the transitional periods following on a change of hours before equilibrium was established have been omitted.

It must be remembered in dealing with the relation between hours of labour and efficiency that whenever hours are shortened a long period elapses before equilibrium and constant conditions are obtained. On the other hand, when hours are lengthened, there is sometimes an immediate reduction in hourly output [**6**].

The relation between hours of labour and output has been studied in two ways :—

(i) by tracing current variations in production extending over a given period such as a day or week ;

(ii) by means of mass data comparing production during two different systems of employment.

Method (i) has two advantages over method (ii). It is a more sensitive test, admitting as it does of the study of hourly variations, and it enables the effects of sporadic factors to be more easily determined, since special note of them can be made as they occur. On the other hand, for its application, it is only rarely that the necessary details can be extracted from existing records [**5,** 12], and arrangements must generally be made for the collection of current data, such as hourly bookings of output. The setting up of special machinery for the purpose is therefore required, and a considerable time must elapse before the results are collected and available for analysis.

This method has been adopted in the investigations into silk-weaving [**9**] and cotton weaving*. Automatic pick recorders were attached to a large number of looms over a long period, and hourly (or similar regular) readings of the output (as measured by the number of picks) were taken. Occasional use has also been made of this method in special instances in other investigations [**1,** 9 ; **2** ; **15,** 12].

For the reasons already given, method (ii) has been used more generally. It possesses the advantage of generally covering a larger number of workers, but on the other hand it can only be applied when two clearly defined systems of employment are available, and is necessarily subject to the limitation that as it deals with the past, the effects of other conditions as a rule can only be roughly gauged. Further, it cannot, save in very exceptional circumstances [**5,** 12] be used to investigate hourly variations in output.

Relation to Output.†

A.—VARIATIONS IN OUTPUT DURING THE DAY.

A study of the variations in daily output at short intervals throughout the day is of special interest for the tracing of typical work curves for different kinds of work, for indicating the existence of fatigue at the end of the day or of a spell of work, and for investigating of the effects of interpolated rest pauses. The results hitherto obtained by the Board's investigators may be summarised as follows :—

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* The actual collection of these data only ended on the 31st December last, and some months must necessarily elapse before they are analysed and embodied in a report.

† To facilitate comparison the output throughout this section is expressed in terms of relative percentage output, *i.e.*, the average output over a given period is taken as 100 and the variations expressed in percentages above or below the average.

(*a*) *Charging of Blast Furnaces* [**5,** 12].—In the heavy labour of charging blast-furnaces by hand, the examination of records giving data of the time in minutes required for each charge and the actual hour when each occurred, disclosed a distinct fatigue effect for the 8-hour shift.

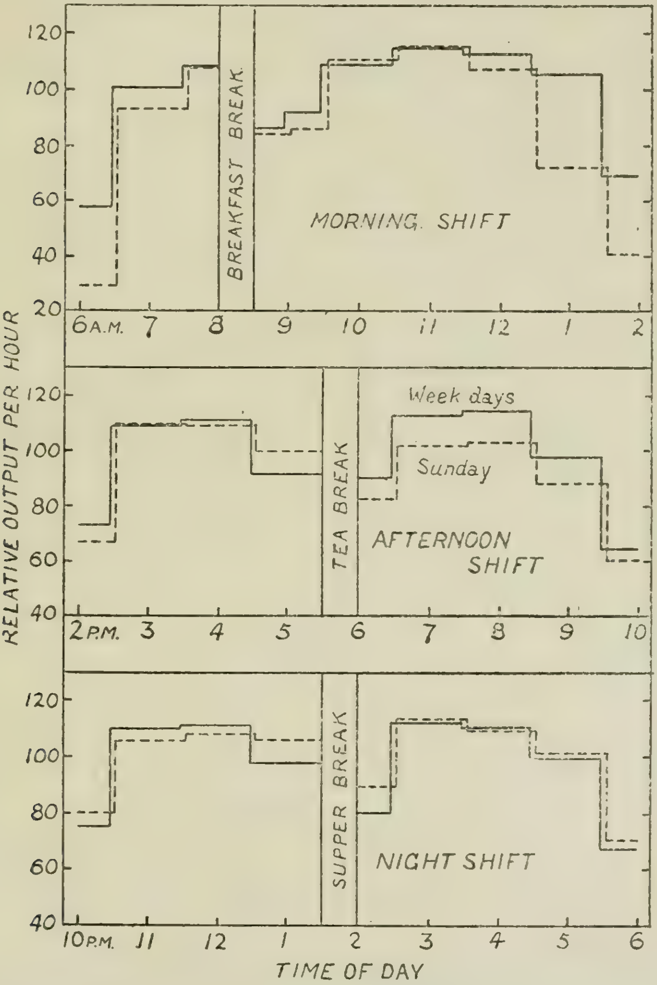

Fig. 1.—Variations in rate of charging Blast Furnace throughout the day.

The above figure indicates :—

(i) that (with the exception of the brief spell from 6 a.m. to 8 a.m.) the rate of charging fell off during the last hour or two of each spell, showing an average decline of 14 per cent. ;

(ii) that this effect became exaggerated during the morning and afternoon shifts of Sunday, when the men worked a continuous shift of 16 hours (6 a.m. to 10 p.m.) in order to enable the shifts to change over.

Silk-weaving [**9,** 26, 46].—In the moderately heavy labour of silk weaving, variations in hourly output during a day of 9¾ hours were observed by means of automatic pick-recorders attached to the looms. The results, when corrected for various extraneous conditions gave the following as a typical curve :—

FIG 2

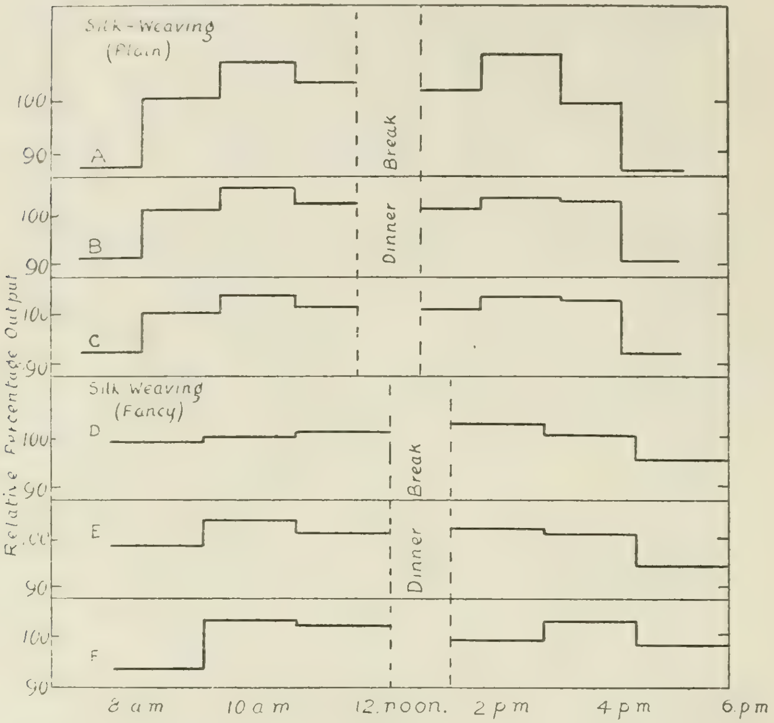

Fig. 2.—Variations in output during the day.
Curve A.—Output of 56 looms during a period of 3 weeks (Jan. 5–26).
,, B. ,, ,, ,, ,, ,, (Jan. 26–Feb. 14).
,, C. ,, ,, ,, ,, ,, (Feb. 16–Mar. 6).
,, D.—Output of 42 looms during a period of 5 weeks (Nov. 17–Dec. 20).
,, E. ,, ,, ,, ,, ,, (Dec. 20–Jan. 31).
,, F. ,, ,, ,, ,, 4 ,, (Feb. 2–Feb. 28).

Here again (as the looms were running right up to the end of the day, and therefore no loss in mechanical efficiency occurred) the noticeable drop during the last period seems to indicate the onset of fatigue. Similar types of curve were obtained in the case of both plain and fancy silk-weaving.

Shell-making [**2,** 10].—In the moderately heavy labour of " ripping " in shell-making, hourly bookings of the shells dealt with enabled variations throughout the day to be studied. The data are admittedly too few to be decisive or even positively suggestive, but the main results may be summarised as follows:—

(*a*) On the 12-hour shift system there is a heavy fall in output during the last hour on both day and night shifts.

(*b*) On the 8-hour shift system there is no drop in output during the last hour of two of the shifts, the drop in the remaining shift being due probably to other causes.

Metal Polishing [**15,** 13, 16].—Farmer has used observations of hourly output of individuals to test the effect of altered methods of work. One common feature of these curves is the immediate response to a short tea interval in the afternoon.

The curves reproduced in Figs. 1 and 2 have evidently certain features in common, notwithstanding the difference in the kind of work carried out. In particular, both show a rise at the beginning of the day and a fall at the end, conforming roughly to the " saddle-back " type of curve which seems to be generally representative of daily work. A closely similar type of curve was found to be representative of engineering work by the American Committee on Industrial Fatigue, both for an 8-hour and a 10-hour plant, the variations being less pronounced in the former [**31**]. Also Muscio [**18**] has shown that a curve following roughly the same course seems to exist in the case of mental tests, whether applied to working or to resting subjects, indicating the existence of some innate diurnal rhythm.

Tinplate.—Vernon has used observations of hourly output to compare the effects of the 6-hour and 8-hour shift in tinplate manufacture [**1,** 10]. The results may be summarised as follows :

TABLE II.—*Comparison of Eight-hour and Six-hour Shifts.*

Eight-hour Shift.		Six-hour Shift.	
Hour of Shift.	Relative Output (Mean of four gangs).	Hour of Shift.	Relative Output (Mean of four gangs).
1st	103	1st	101
2nd	106	2nd	100
3rd	96	3rd	96
4th	99	4th	104
5th	98	5th	105
6th	99	6th	97
7th	107	—	—
8th	92	—	—

Vernon points out that the hourly outputs on the 6-hour shifts vary distinctly less than those on the 8-hour shifts, and that whilst the values agree in showing an initial output above the average followed by an output below it, then a considerable rise and in the final hour a considerable fall,* they differ in that the middle period of low output lasted four hours for the 8-hour shift and only one hour for the 6-hour shift.

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* A similar variation in output was observed by Vernon in the hand-tapping of fuse sockets [**25,** 153].

Length of Spell.—The study of variations in output throughout the day is also of use in illustrating the effects of spells of different lengths [**26,** 153]. In Fig. 1, for instance, the only spell that does not show a reduction in output towards the end is the short early morning one of two hours. In every other case, there is a drop in the last hour, the extent of which corresponds roughly with the length of spell.

Rest Pauses.—The importance of breaking up spells by means of suitable rest pauses has already been demonstrated by Vernon for the Health of Munition Workers' Committee [**26,** 161]. The value of systematic rest pauses is illustrated in two of the Boards' investigations. The first [**10,** 28] gives the results of an experiment introduced in the press-room of a boot factory. Instead of the usual system of employing two girls on each double press, teams of three girls were formed, each operative working 40 minutes out of the hour and resting 20. An increase in output immediately resulted ranging from 34 to 75 per cent., and averaging 44 per cent. over the six presses concerned. The experiment involved, of course, the employment of 50 per cent. additional workers, but it is valuable not only in illustrating the effect of rest pauses but also practically in indicating a method whereby output can be increased without incurring the expense of purchasing new machines.

In the second investigation [**15,** 54] a comparison is made between the effects on output in *roughing* (one of the processes in metal polishing) of

(*a*) organised rest-pauses of five minutes each hour ;
(*b*) unorganised rest-pauses (*i.e.* such as the rougher herself made use of without any interference).

This shows that during the period of organised rest-pauses the rougher required on the average 31 minutes 20 seconds to rough one dozen spoons, as compared with 32 minutes 30 seconds during the unorganised rest-pause period, corresponding with an increase in output of 4 per cent.

The average times required for a given task for three days under both systems are given in Fig. 3.

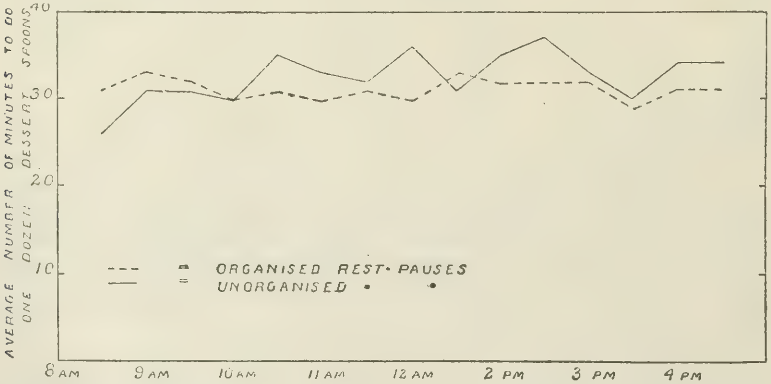

FIG. 3—Time required to rough one dozen dessert spoons with organised and unorganised rest pauses.

This indicates that there is far greater regularity in the curves representing the days in which there were organised rest-pauses and suggests that the onset of fatigue is checked by the systematic introduction of rest-pauses, probably through allowing rhythm to play a greater part in the work.

B.—VARIATIONS IN OUTPUT DURING THE WEEK.

The variation in daily output throughout the week is of use as a test whether fatigue is normal or pathological, in other words, whether there is complete recovery during the night's rest. It also shows the effects of different incentives, such as anticipation of pay or holidays.

Silk-weaving and Boot-making.—[**9,** 35, 37, 52 ; **10,** 16]. The data for these industries are summarised together in the following table, the average daily output (excluding Saturdays) being taken as 100 :—

TABLE III.—*Variations in Daily Output.*

Process.	RELATIVE OUTPUT.						Percentage reduction on Sat.
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	
Silk weaving (plain)	100·1	103·2	101·6	102·2	100·3	92·4	*9·0*
Do. (fancy) ..	98·0	100·4	101·1	103·0	99·4	97·9	*2·5*
Boot-making and finishing.	100·5	103·0	106·0	107·5	98·5	84·5	*18·1*
Do. do. ..	100·0	104·0	105·2	106·5	107·1	77·0	*26·4*
Do. do. ..	99·5	102·6	102·0	103·6	102·7	89·4	*12·3*
Do. do. ..	100·9	101·2	102·1	102·9	97·5	95·4	*5·4*

Charging of Blast Furnaces.—Vernon [**5,** 16] has calculated for a fifty-week period the average rate of hand-charging on each day of the week for night and day shifts of eight hours. The variations found are shown in the following table :—

TABLE IV.—*Variations in Rate of Charging.*

	Relative Output.						
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
Day Shift ..	95	99	105	101	102	103	86
Night Shift ..	98	101	105	104	100	99	102
Mean ..	96	100	105	103	101	101	94

Apart from the abnormal Sunday values, the general distribution follows that observed in the previous table in that the "Monday effect" is present and a maximum is reached about the middle of the week.

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* The term "Monday Effect," to indicate the consistent reduction in output during the early part of Monday, was first used by Stanley Kent [**29**].

The results given in Table III. and IV. are graphically represented in Fig. 4 and admit of the following conclusions :—

(1) Output is always low both on Monday and at the end of the working week.

(2) The general shape of the curves is consistent with output being controlled by two opposing factors, (*a*) increased efficiency due to practice, which causes a rise in output, and (*b*) fatigue effects, which accumulate during the course of the week and tend to bring about a gradual fall in output.

(3) These opposing factors vary in strength under the different conditions (such as duration of working hours, and character of the work) found in different occupations, and in consequence output may reach its maximum on the second, third, fourth or fifth day of the working week.

(4) The distribution of output throughout the week is also often affected by some special incentive such as booking up or pay day.

C. VARIATIONS IN OUTPUT OVER LONGER PERIODS.

In addition to variations in hourly and daily output, variations over longer periods such as a week or a month have been studied in certain industries. These are of special value in enabling us to trace seasonal influences and to compare the effects of different systems of employment.

Seasonal Variations.

(*c*) Vernon [**5,** 39, 66 ; **1,** 13] has shown that in heavy work, especially when it involves exposure to high temperatures, output undergoes a consistent seasonal variation, being with very few exceptions greatest in winter, least in summer and intermediate between the two in spring and autumn. The data collected by him are summarised in the following table :—

TABLE V.—*Seasonal Changes of Output.*

Occupation.	Relative Output during		
	Winter (Dec.–March).	Spring and Autumn.	Summer (June–Sept.).
Men charging blast furnaces.. ..	105·0	106·5	88·5
Open hearth steel melters at Works C	107·7	102·0	96·2
Open hearth steel melters at Works D	85·7	85·1	84·8
Open hearth steel melters at Works F	102·5	100·5	97·2
Open hearth steel melters at Works J	102·5	104·6	102·8
Rolling Mill men at Works III. ..	107·0	106·5	107·0
Rolling Mill men at Works V. ..	124·0	118·0	111·0
Rolling Mill men at Works VI. ..	105·2	98·4	96·5
Men puddling wrought iron	104·7	102·2	96·0
Tinplate millmen	103·3	99·9	96·9
Mean temperature at Greenwich	40·0°	48·5	60·2°

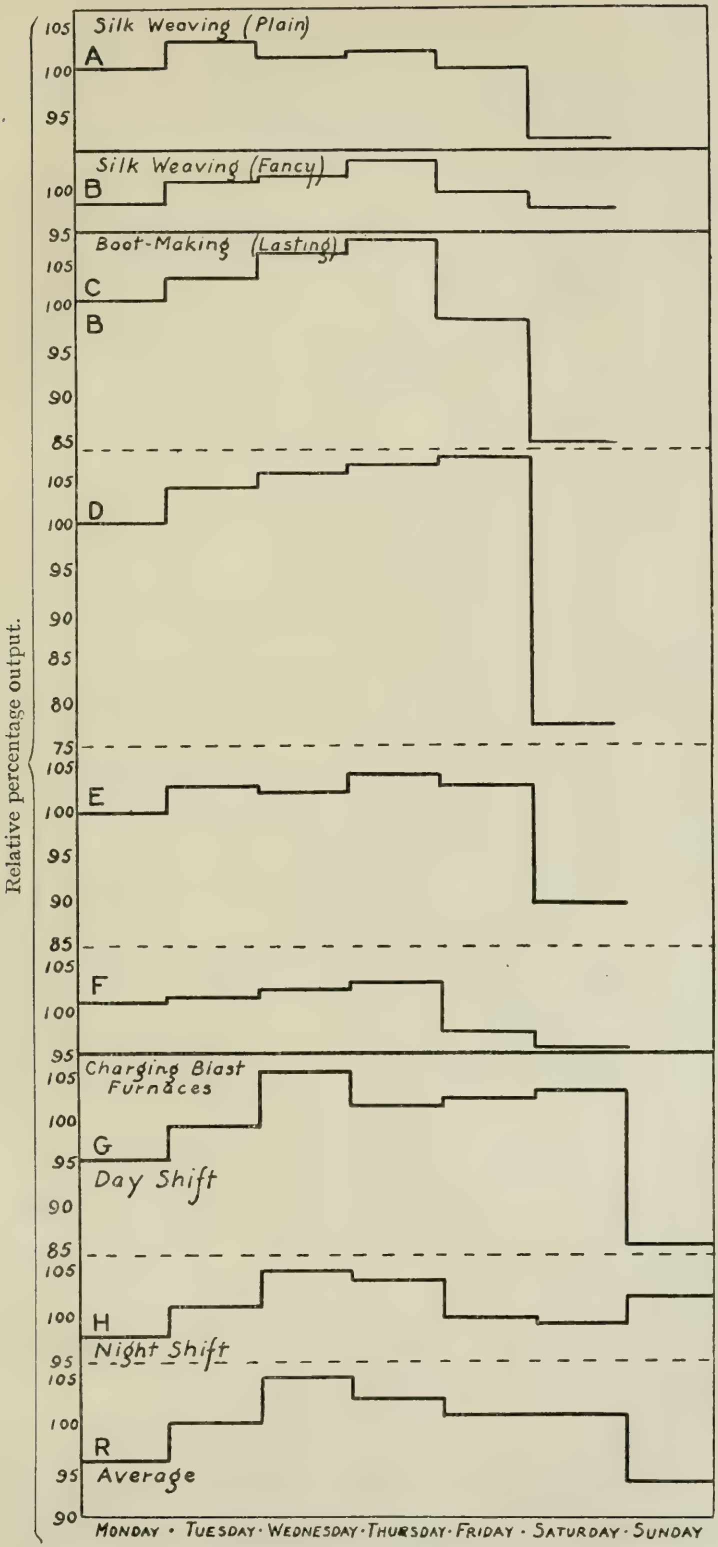

FIG. 4.—Variations in output during the week.

A variation in the opposite direction was clearly traceable in the process of silk-weaving [**9,** 41, 54] (as is shown in Fig. 5).

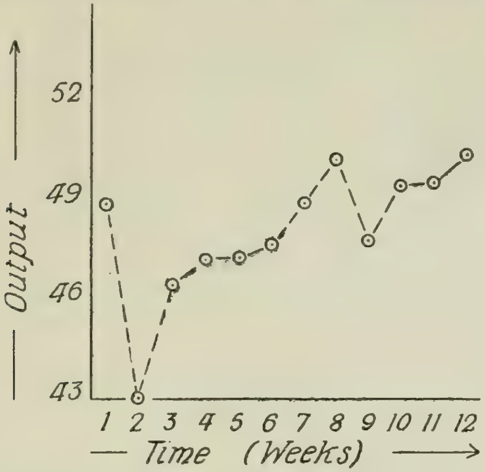

FIG. 5.—Average hourly output in each week from December 15 to March 6 (Silk Weaving).

Except for the abnormal Christmas week, there is a practically continuous increase throughout the period. As will be seen later this effect is to be ascribed largely to the gradual reduction in the use of artificial light.

Effects of Different Systems of Employment.

Output data were used to indicate the effects of different systems of employment by Vernon for the Health of Munition Workers' Committee [**26,** 153]. The same method has been applied by the Board in comparing the effects of shifts of different lengths in the tinplate and steel trades.

Tinplate.—For millmen's work in tinplate manufacture [**1,** 6] use was made by Vernon of existing records of output kept by various factories. These were examined and after correction for other variables tabulated so as to compare the average hourly output under the two systems. The following table summarises briefly the results obtained :—

TABLE VI.

Comparison of Shifts of different lengths. (Tinplate manufacture).

Factory.	Shifts Compared.				Percentage increase in average hourly Output.
	Length.	Period Covered.	Length.	Period Covered.	
A	8-hour	6 years	4-hour	7 months	11·5
C	,,	97 weeks	6-hour	96 weeks	8·5
D	,,	19 ,,	6-hour	19 ,,	10·6
E	,,	10 ,,	6-hour	10 ,,	4·7

The validity of the above results is naturally limited (i) by the number of records available, and (ii) by the periods during which the respective shifts were worked [**6**]. Vernon states that the data in regard to Factory A are the most reliable, and estimates that when 6-hour shifts are worked the hourly output is about 10 per cent. greater than when the 8-hour shifts are worked.

Iron and Steel.—In iron and steel manufacture there were, until the beginning of 1919, two shifts system in simultaneous operation, three 8-hour shifts being worked in some districts and two 12-hour shifts in others. When the Board started their enquiry, therefore, there was an excellent opportunity of studying the effects of these two systems. Shortly after the investigation had begun, however, an agreement for a universal 8-hour shift became operative, so that the original purpose of the enquiry could not be fulfilled. Nevertheless, by means of existing records, Vernon succeeded in throwing some light on the question in respect of certain processes.

In the case of blast furnaces [**5,** 20] the conditions of manufacture are so changeable that they mask any variation in output due to altered hours of work. Vernon, however, adduces some evidence to show that the lost time on the 8-hour shift is less than on the 12-hour shift, and that the efficiency with which the blast furnaces are run is correspondingly increased.

In steel-making by the open hearth process, considerable information was obtained from the examination of the records of the output from the furnaces, kept at various works [**5,** 38]. In one works [**6,** 5], in which a reduction in length of shift from 12 to 8 hours was made in June, 1912, complete records of output of ten 40-ton furnaces were available for every week from 1910 to 1914, thus allowing of a comparison between two approximately equal periods under the different systems, during which the total hours worked were the same. An analysis of these records showed that, taking each period as a whole, the relative output of all the furnaces rose from 100 to 107. The effect of the reduction in hours, however, is shown more clearly in the following diagram :—

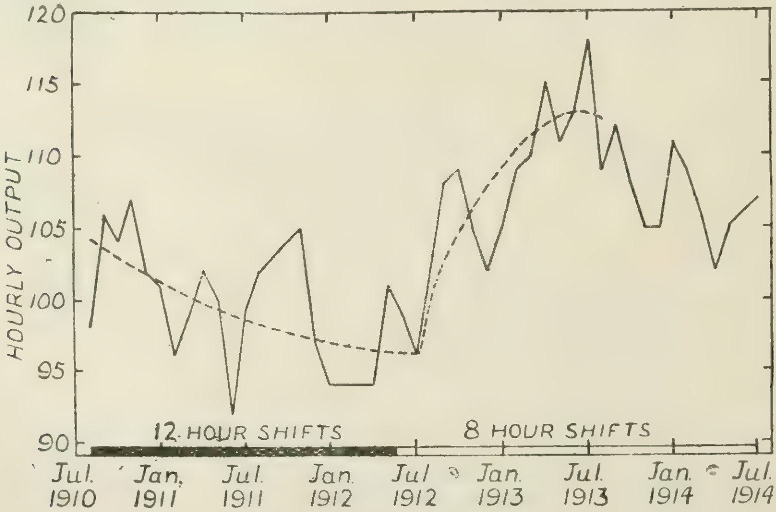

Fig. 6.—Output from Steel Furnaces.

On this Vernon remarks [**6,** 5] :—

> The dotted line . . . . is meant to represent average and . . . . . shows a gradual fall of output during the 12-hour shift period from 104 to 96. In June, 1912, the men went on to the 8-hour shifts, and for the first two months there was no definite improvement of output. Then it began to mount up rather irregularly, but it did not obtain its maximum until July, 1913, or 13 months after the reduction of hours. During the next twelve months it fell away considerably and then, with the advent of the war, the conditions of production were changed and comparable output data were no longer obtainable. The fall of output noted during the 12-hour shift period and the latter half of the 8-hour period is possibly due to the same cause, though I am ignorant as to its nature. . . . If the dotted line be taken as a fair criterion, this change of shift caused the output to increase from 96 to 113 or by 18 per cent., but if the output be averaged from June, 1913, onwards, it comes only to 109, or it shows an increase of 14 per cent. on the 1912 output.*

Less complete data for six 30-ton acid furnaces kept at another works showed that on an average the output increased only 2 per cent. when the shifts were shortened [**5,** 39].

In the rolling of steel the effect on output of reduction of hours is difficult to estimate, because output is often seriously interfered with by delays in supplying ingots to the mills, and it is generally impossible to make the necessary corrections for this when dealing with past records.

In two mills, however, Vernon gained access to records suitable for analysis [**5,** 63]. In one, in which the same product was made throughout and in which the supply of ingots was alleged to be always adequate, the effect on output of the reduction from 12 to 8-hour shifts was apparently so small as to be negligible. In the second works, in which records of output and all delays occurring were kept, a reduction of hours from 64 to 60⅔ for day shift and from 58 to 53½ for night shift was followed by an immediate increase in output of 21 per cent. and 12 per cent. respectively. As Vernon points out, however, this striking result was probably due for the most part to the advent of a new manager, and to the steps taken to improve the organisation of the department.

Other Relations.

Vernon has compared the effects of two shifts of different lengths by quoting the number and duration of rest pauses taken.

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* It may be of interest to compare this increase in output due to shortened hours with the increase brought about by mechanical improvements. At one works on 8-hour shifts throughout, the total output of eight 60-ton furnaces were ascertained every week for 13 years, during which several improvements in plant were successively introduced. In this respect the whole period could thus be divided up into three stages, the output in each being summarised as follows [**5,** 42] :—

	1906-1907.	1908-1910.	1911-1918.
	Cold metal. Furnaces hand-charged.	Hot metal. Half furnaces machine-charged.	Hot Metal. All furnaces machine-charged.
Relative output	67	89	100

He found [**1,** 9] by direct timing that in the rolling process of tinplate manufacture men on 6-hour shifts took 3·6 rests per hour of an average duration of 2·85 minutes (a total average duration of 10·2 minutes per hour), whilst men on 8-hour shifts took 3·6 rests per hour of an average duration of 3·42 minutes (a total average duration of 12·5 minutes per hour).

The use by Vernon of the other methods mentioned on p. 23 led to negative results.

SECTION 3.—OTHER CONDITIONS OF EMPLOYMENT.

Introduction.

The present section deals with the effects of *conditions of employment other than hours of work*, or, in other words, the workers' environment. They comprise temperature, humidity, ventilation and lighting, and all other physical conditions constituting the impersonal factors in human efficiency, such as noise, vibration and dust, though the reports of the Board hitherto published deal only with the first four of these.

The pathological aspect of such conditions or their relation to health has for many years been the subject of research, but, so far as can be ascertained, no systematic industrial investigation of their physiological and psychological effects, as shown in their relation to efficiency, has hitherto been undertaken. Yet the latter have a special sensitiveness not possessed by the former, which deal only with the grosser consequences of environment.

For the study of the effects of these conditions the same test has been used for the most part as in the case of hours of labour, namely output. The ideal circumstances for an investigation of this kind are the converse of those already mentioned (p. 17), namely, uniform hours of employment and technical considerations, and only the one hygienic condition concerned variable. These circumstances are for the most part difficult to secure otherwise than approximately in practice, but by introducing certain corrections, important information has been obtained as to the relation of temperature, ventilation and lighting to fatigue and efficiency.

In making practical suggestions, the relation of these conditions to technical effects and requirements must be taken into account. There are, for instance, many processes (such as most processes in boot and shoe manufacture) in which the worker's environment is unaffected by and independent of the conditions of manufacture. These present no difficulty so far as technical considerations are concerned. There are others (such as steel melting, tinplate rolling and many laundry processes) in which the environment is unfavourably *affected* by the conditions of manufacture. This, however, is only incidental and not essential to the process, so that the investigator has a free hand in suggesting improvement. Finally, there is a third class of process (such as the weaving of certain kinds of cotton and linen goods) where a more or less unfavourable environment is *required* for manufacturing purposes. These naturally present the greatest difficulty, and in practice all that can be done is to arrive at a compromise by bringing about some degree of physiological improvement without any seriously harmful technical results.

Temperature.

Vernon has shown [**1**, 13] that in tinplate manufacture the output from the rolling mills is greatly influenced by the temperature of the environment. The effect is, of course, closely related to the seasonal variations in output already referred to (see p. 32), as the following figure shows :—

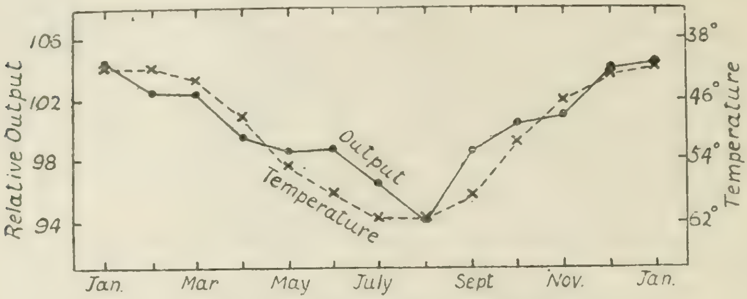

Fig. 7.—Seasonal variation of output and of temperature.

A closer estimate of the effect of temperature was obtained by grouping the weekly output data for five factories according to the mean weekly temperatures as recorded in the district. The results are given in the following table :—

TABLE VII.—*Output in relation to Temperature* (*Tinplate*).

Factory.	Total Weeks Investigated.	Mean External Temperature during Week.						
		Under 40°	40° to 44·9°	45° to 49·9°	50° to 54·9°	55° to 59·9°	60° to 64·9°	65° and over.
A ..	116	102·1	102·3	100·0	99·6	98·9	98·1	(94·0)
B ..	332	104·8	103·3	100·8	98·9	98·1	96·7	(93·7)
C ..	193	100·3	103·9	103·5	100·5	99·1	93·4	(95·5)
D ..	203	105·3	105·2	102·3	99·9	98·6	96·8	(94·0)
E ..	55	110·0	105·7	102·3	102·2	99·6	94·4	(90·0)
Total weeks at each temperature.		78	167	200	122	184	130	17

which shows that the output may vary by as much as 20 per cent. between the extremes indicated. Vernon, however, points out that weekly output variations by no means express the full effect of temperature, since in each week the variations in temperature from day to day and from shift to shift are considerable and have a corresponding effect on the output at the moment. He estimates that in Factory E (see Table VII.) the output of the shifts during the hottest weather was probably 30 per cent. less than during the coldest weather.*

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* Similar effects, observed by Vernon in various processes in the iron and steel industry, have been already described under the heading "Seasonal Variations" (see p. 32).

An opposite effect* (viz., increase in output with temperature) is suggested by observations made in silk-weaving by Elton [**9,** 37], who plotted the average hourly rates of output in a silk-weaving mill against the average temperatures for each half day for 12 weeks. The results are not conclusive, but a positive and significant correlation co-efficient for mornings and afternoons (0·29±0·09 and 0·27±0·09 respectively) between rate of output and temperature were obtained, indicating that for the range of temperature studied (56° to 65° Fahr.) output tends to increase with temperature. It should be observed, however :—

(i) that as the investigation was made during the winter, the temperatures are low and do not approach those studied by Vernon ;

(ii) that the temperature of the air probably has a physical effect on the weaving, a moderate rise being beneficial.

Humidity.

Some relationship between air humidity and output is stated by Vernon to exist in the case of the rolling process in tinplate manufacture [**1,** 26]. He found, for instance, in one factory that during 60 weeks with a mean temperature of 60° or more the mean output fell by about 3 per cent. when the relative humidity of the air was above 80 per cent. The results may be summarised as follows :—

TABLE VIII.—*Effect of Air Humidity on Output* (*Tinplate.*)

Relative Humidity of Air.	Mean Temperature of 60° or more.	
	Observations (weeks)	Mean Output
Under 70	6	97·0
70 to 74	16	97·2
75 to 79	23	97·4
80 to 84	11	93·9
85 and over	6	94·2

A similar but smaller effect was found to exist for two factories during weeks when the mean temperature was 55° or more, whilst in another factory no relation between humidity and output could be traced.

The study of air humidity in relation to output is sometimes complicated by the fact that the technique of a given process is affected by the humidity of the air at the time. An instance of this is to be found in the case of silk-weaving [**9,** 40], where Elton states that he was unable to discover any relation between humidity and efficiency owing to the disturbing effects of variations on the different classes of textile yarns (silk, cotton, wool and viscose) used in the material produced.

Another case of a rather similar type occurred in connection with the seasonal variations in output observed in blast-furnaces already referred to (see p. 32), and illustrates the necessity in estimating fatigue effects of ensuring either that other conditions are constant or that their variations are allowed for [**5,** 17]. Table V indicates that a marked reduction in the rate of charging blast-furnaces occurred during the summer months but, before this can be ascribed to lower efficiency, any differences on the technical side occurring in summer must be compensated for. Air contains moisture, which in its passage through the furnace is decomposed with the absorption of heat. Now the amount of moisture in air, and, therefore, the heat absorbed for a given volume of air is greater in summer than in winter, so that in summer the productive efficiency of *the plant* is somewhat lowered.

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* A similar difference between steel-making and silk-weaving exists in the seasonal variations observed (see p. 32).

Vernon investigated this point in the case of two furnaces over 5 and 3 years respectively, and found that on the average the output was 1·5 per cent. greater in winter than in summer. He concludes, therefore, that even supposing the whole of the observed seasonal variations of output to be due to this course, it cannot account for more than a small fraction of the much greater seasonal variations in the rates of charging contained in Table V.

Ventilation.

In considering the effect of ventilation on fatigue and output, the particular aspect concerned must be clearly defined. The change of air in the environment (if we may so define ventilation) may obviously be regarded from different points of view in respect of its effects on the workers. Pathologically, it may be considered as a vehicle for the removal of dust or of the germs of infection; physiologically, as a stimulus to muscular activity; and psychologically, as a means of reproducing to some extent the invigorating conditions of outside air. The work hitherto carried out by the Board is concerned with the second of these effects, and, in particular, the cooling power of moving air.

Some striking results in this respect were obtained by Vernon in the tinplate industry [**1,** 21]. Some of the rolling mills were provided with artificial means of ventilation, such as paddles or air douches, whilst others simply depended upon natural means. The seasonal variations in output (p. 32) in the different mills is given in the following table :—

TABLE IX.—*Comparison of Output in Summer and Winter (Tinplate).*

Factory.	State of Artificial Ventilation.	Mean Output in—		Percentage Reduction in Summer.
		December & January.	July & August.	
A	Good	100·5	97·5	3·0
B	Moderately good ..	102·5	97·0	6·4
C	Moderate (or none) ..	105·5	94·5	10·4
D	None (good natural)	104·5	93·0	11·0
E	None (poor natural) ..	108·0	93·5	13·4

The effect of the good ventilation is clearly shown in the evenness of output in Factories A and B compared with Factories D and E.

A similar result is shown by comparing the output in the different factories grouped according to the external temperature. (Fig. 8.) The smaller reduction in the well-ventilated factories during the hot weather is very marked.

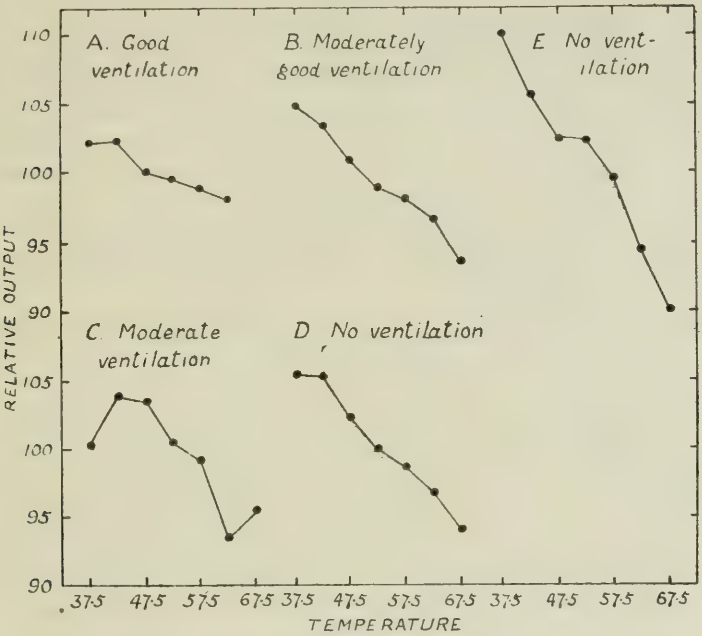

Fig. 8.—Output in relation to temperature.

The extent to which atmospheric conditions vary in their physiological effects has been explored by Hambly and Bedford by means of the kata-thermometer in a large number of boot factories [**11**].

The kata-thermometer, an instrument designed by Leonard Hill, consists of a large-bulbed alcohol thermometer so constructed as to enable the time taken for the column to fall from 100° to 95° F. (*i.e.*, through a range approximating to the temperature of the body) to be measured when exposed to air at a lower temperature than itself. When the bulb is uncovered, the instrument is known as the dry kata, and when covered with thin fabric moistened with water, as the wet kata. The dry kata measures the cooling power of the air due to convection and radiation, and the wet kata that due to convection, radiation and evaporation. By the use of suitable conversion factors the rate of cooling the bulb can be found in terms of millicalories per square centimetre of surface irrespectively of the particular instrument used. Hill [**28**] has suggested definite numerical standards indicating air conditions suitable for different types of work (sedentary, heavy, very heavy), and in proper hands the instrument can be used to give very valuable information as to the physiological aspect of ventilation. It might, for instance, be used to test the adequacy of methods adopted in tinplate rolling mentioned above.

The report by Hambly and Bedford deals solely with the katathermometric data collected, and the correlation of the conditions observed with fatigue and efficiency is not yet complete.

Lighting.

The effects of lighting on production were studied with interesting results by Elton in silk-weaving [**9**, 31, 41, 54], which is a fine process specially susceptible to variations in illumination. The investigation was based on hourly output data recorded automatically on a large number of looms in two weaving sheds over a period of three months. By treating these data in various ways, the relation of lighting to output could be clearly traced. The following table, for instance, shows the distribution of output (corrected for certain variables) from 56 looms during the week ended December 20th, 1919 :—

TABLE X.—*Distribution of output through the Day in Winter (Silk-weaving).*

Period (a.m.)	Output.	Period (p.m.)	Output.
7.30 to 8.30 a.m. . .	45·8	1 to 2	47·5
8.30 to 9.45 a.m. . .	49·3	2 to 3.15	52·1
9.45 to 11	52·1	3.15 to 4.5	50·9
11 to 12	48·3	4.15 to 5.15	41·9

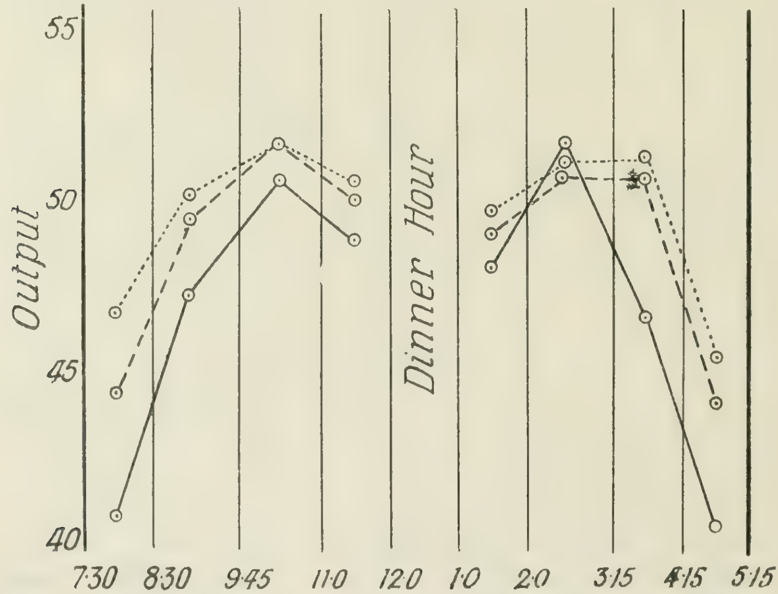

Fig. 9. Distribution of Output (Hourly Averages) during three consecutive Periods, each of three weeks. (Silk-weaving).
Full line represents Jan. 5th to Jan. 24th.
Broken ,, ,, Jan. 26th. to Feb. 14th.
Dotted ,, ,, Feb. 16th. to Mar. 6th.

The use of artificial light was confined to the first and last periods, and to this must be attributed in great part the heavy drop in output observed, since, as shown by Fig. 9, at a later season when artificial light was no longer used the reduction in output at the beginning and end of the period of employment, though still present, was much less marked.

Elton concludes that under artificial illumination production falls, even if electric light of sufficient intensity is provided, and that the magnitude of this fall is of the order of 10 per cent. of the daylight value of the rate of output. He also points out that after natural lighting is resumed some time elapses before the output becomes normal and the operative accommodates himself to the new conditions.

Conclusion.

The chief immediate value of the class of investigation described in this section lies perhaps less in actual discovery than in enabling definite numerical values to be attached to the effects observed, the occurrence of which is indeed often already well known. If, for instance, by these means proof can be adduced that human efficiency is reduced by causes that can be remedied (often without much difficulty as in the case of the tinplate rolling mills), the employer and workman have a common interest in bringing about the necessary improvement. But these investigations have an additional and wider aim, in that they form the principal means of studying first principles relating to the optimum conditions of work for the operatives of the future. The average workman spends about one quarter of his adult life in the factory, and his environment there is almost as important as any other condition of his living.

SECTION 4.—METHODS OF WORK.

Introduction.

The previous section has been limited to the impersonal factors in fatigue and efficiency, but no less important is the part played by the worker himself. This has already been long realised in the United States, where Taylor, Gilbreth, and others have succeeded in raising the study of the personal factor in industry to the level of a definite science. In this country little has yet been accomplished on these lines*, but at an early stage of their existence the Board decided to devote part of their activities to the study of two principals generally regarded as underlying human performance in industry, namely (a) vocational selection and guidance, and (*b*) time and motion study, and as an initial step to publish summaries of the work hitherto done in each of these subjects with complete bibliographies [**12; 14**].

Vocational Selection and Guidance.

Among the factors affecting human efficiency in industry, some method of ensuring that so far as practicable every worker shall be placed *ab initio* in an occupation for which he his naturally fitted is perhaps one of the most important. The high labour turnover commonly occurring amongst beginners employed in factories [**13,** 16] tends to show that the initial selection of an occupation is often a matter of chance and that any permanent employment subsequently obtained is only secured after a process of trial and error. Apart from other considerations, there can be nothing more discouraging than the realisation that a long period of training has been only partly effective and that the time so spent might have been used more profitably in another sphere.

The recognition of these facts has led in recent years to the development of vocational selection and guidance, the former having for its object the cataloguing of various occupations according to the aptitudes and capacities required in them, the latter the examination and testing of applicants with a view to advising them as to the occupations for which they are naturally fitted.

It is not, of course, contended that the selection of an occupation should depend solely on the application of these methods. Choice is often limited by local circumstances, and in addition there may be other reasons outweighing any indications derived from vocational tests. Instances, however, must often arise where there is no predisposing tendency towards one of several available occupations, and it is here that vocational guidance methods are likely to be of the greatest value. A boy or girl found to be naturally unsuitable for one occupation will almost certainly be found suitable for another. Different occupations clearly demand different aptitudes, and vocational guidance as it progresses will merely indicate to the applicant whether one occupation is more suitable in his particular case than another.

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* Interest in the personal factor in industry has greatly increased since the time when the Board was constituted and even during the year covered by the present report. This is shown by the formation of the National Institute of Industrial Psychology, a self-supporting organisation initiated to study and give practical effect to these principles.

In view of the above considerations, vocational guidance may be regarded as having a direct bearing on human efficiency and fatigue in industry. In particular, the degree of fatigue induced by a given task must clearly depend partly on the inherent capacity of the worker to perform that task, and the study of vocational selection was contemplated by the Board on the grounds that it is in its very nature a preventive of fatigue. Research is now being undertaken on the subject, but progress is necessarily slow and the published work is at present limited to a series of three short studies [**16**].

The first of these [**16, A**] is based on an investigation conducted by Muscio amongst compositors, readers, and monotype key-board operators in four printing works. The procedure adopted was as follows :—

(1) The work was closely observed and the particular capacities that seemed to be demanded by it noted.

(2) Suitable tests of these capacities were devised.

(3) The operators were graded from an independent source, generally from the opinion expressed by the manager or foreman, as to the proficiency of each individual as a compositor.

(4) The tests were applied and a second grading based on these tests obtained.

(5) The two gradings were compared, and by applying the method of partial correlation such tests as were shown to be unnecessary or undesirable eliminated.

(6) The independent grading was correlated with a grading based on the remaining tests.

In the case of compositors, the following capacities were first tested as the result of observation of the work.

(*a*) Dexterity (*Match Stick Insertion Test*).

(*b*) Rapidity of observation (*Two Cancellation Tests*).

(*c*) Immediate memory (*Substitution Test*).

(*d*) Visual Perception of Form (*Form Board Test*).

(*e*) Intelligence (*Directions Test*).

Of these, one of the cancellation tests, the form board, and substitution tests were subsequently discarded, and the final results based on the remaining three tests.

The results obtained at one of the works may be graphically represented as follows :—

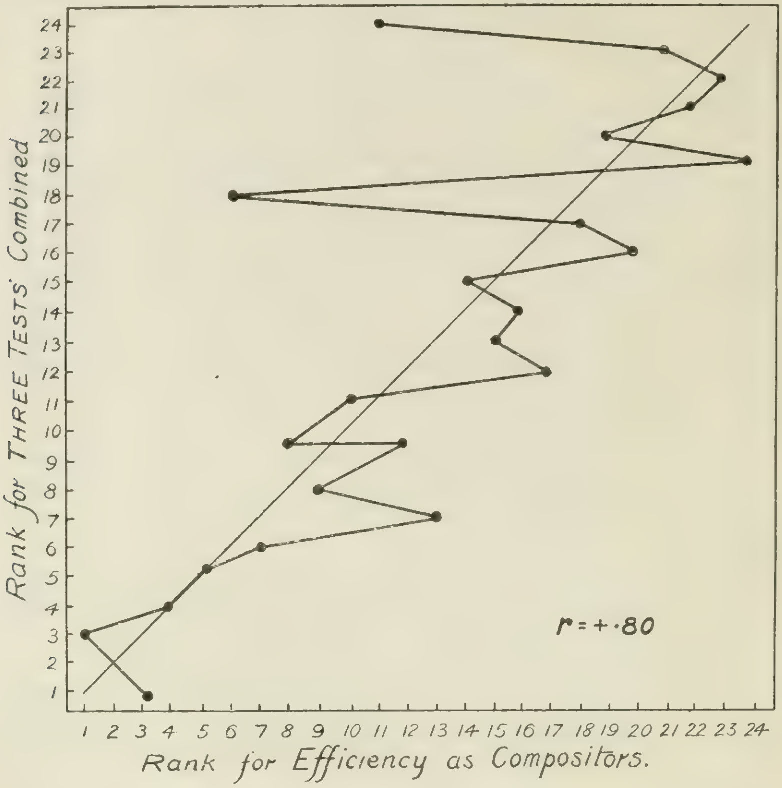

Fig. 10.—Graphical representation of the degree of correlation at PWB between composing efficiency and total score in the *Cancellation*, *Match Stick Insertion*, and *Directions* tests.

The ordinates are the ranks for the tests :—that is, " 1 " indicates the *rank* of the compositor who made the best performance in the tests ; " 2 " that of the compositor who made the second best performance, and so on. The abscissæ are the ranks for composing efficiency. The dots represent the individual compositors, and the degree of correlation is indicated by their nearness to the straight diagonal line, which represents a possible *perfect* correspondence between the rankings for composing and total efficiency in the three tests (an *r* of + 1). If a dot falls on this line, the compositor represented by it occupies exactly the same position in the tests and composing rankings. Thus, the compositors represented by the fourth and fifth dots (from the bottom) occupy the same rank in the tests and in composing. While this seldom happens, the distance of the dots from the line of perfect correlation is rarely considerable.

Similar results were obtained in the case of the compositors in another works (PWA), the co-efficient of correlation here being + 0·71.

On the general significance of these results Muscio remarks (**16,** 35, 36) :—

> Efficiency in composing is dependent upon four kinds of factors namely :—
>
> (1) Trade knowledge and experience ;
> (2) Specific psycho-physiological capacities ;
> (3) General health ;
> (4) "Moral" qualities, such as "application" or ambition.
>
> The importance of the first of these may be judged from the length of the printer's apprenticeship—seven years. This period is undoubtedly too long ; but several years are certainly necessary for the apprentice to acquire the knowledge of the thousand and one things that must be known by the expeditious compositor. A man may be perfectly endowed with the psycho-physiological qualities required by a printer, and have good general health and "application" ; but he will not be efficient as a compositor until he acquires a considerable amount of trade knowledge.
>
> It is important to recognise, on the one hand, that a compositor *may* become fairly efficient without any *special* endowment of the qualities required for his occupation. When this happens, trade knowledge and moral qualities (if general health is fairly robust) compensate for a certain lack of these qualities. On the other hand, a compositor may be relatively inefficient, not because he is lacking in these qualities, but because he lacks trade knowledge or health or "character." Lack of trade knowledge would appear to be not so uncommon as might be expected. This is sometimes due to the master printer not giving the apprentice a satisfactory opportunity of acquiring it. At the present time it is, perhaps, most often due to a lack of desire on the part of the apprentice to acquire the knowledge.
>
> The point to be emphasized is that composing efficiency does not depend simply upon the possession by the compositor of certain psycho-physiological capacities. This has to be borne in mind in considering the correlation co-efficients given above. Efficiency in the tests that were used was presumably determined primarily by the special capacities required for the tests and not by extraneous factors. If efficiency in composing were similarly determined—that is by the special capacities required for composing—we should expect an almost perfect correlation between efficiency in the tests and efficiency in composing. The correlation obtained was not perfect, which is as it should be, seeing that factors enter into efficiency in composing which do not enter into efficiency in the tests. Indeed, when it is realised how large a part in a compositor's efficiency is played by trade knowledge alone, it may seem surprising that the correlation co-efficients are as high as they are. In the circumstances, indeed, their size indicates that the functions brought into operation in the performance of the tests are distinctly important for composing efficiency.

Some preliminary tests were also carried out on readers and monotype keyboard operators. The numbers were too small to yield definite conclusions, but the results suggest that the *rapidity of observation*, a certain degree of *intelligence*, and *immediate memory*, are required by these workers as well as by compositors.

In the second study on vocational selection [**16, B**], Muscio deals with the measurement of physical strength of 2,300 youths in Manchester and industrial Essex. He points out that many forms of work make special physical demands on the worker, and that inadequate muscular development induces unnecessary fatigue and inefficiency,* and in particular suggests tentatively that with regard to the subjects tested, possibly 10 per cent. of those who become engineering apprentices do not possess the physique required for engineering work, so that some decrease in fatigue and inefficiency could be effected by guiding these into vocations where physical strength is not required and by substituting for them others of more adequate physique.

His other conclusions are :—

(i) that the muscular strength test devised by Martin [**30**] (based on tests for certain groups of muscles) is unsatisfactory for general industrial work, chiefly because results obtained by it are partly a function of the particular operator ;

(ii) that a combination of grip and weight gives a useful indication of general strength, though a better indication would almost certainly be obtained by the addition of a suitable test of the strength of the forearm flexors ; and

(iii) that the Essex adolescent males engaged in engineering are consistently superior physically to Manchester adolescent males engaged in the same type of work.

A set of percentile tables is appended by the use of which the general strength of an individual may be estimated from his grip and weight.

A somewhat similar investigation [**16, C**] was conducted by Farmer amongst girls employed in a confectionery factory. The subjects selected were manual workers, paid on a piece rate system, and the measurements taken were chiefly those of the arms, hands and fingers. In each process the workers were divided into two groups (A and B), composed of those whose output was high and low respectively, and the physical types of both groups were compared so as to ascertain whether proficiency is related to any particular type.

The results indicate that two distinct types exist, designated long-spanned and short-spanned, and that the long-spanned type manifests itself in the A group amongst the packers, and in the B group amongst workers in the packet department and dippers, suggesting that a long-span is desirable for packing and a short-span for the other kinds of work. This conclusion, however, cannot be regarded as definite until it is known how far the occupation itself develops these characteristics ; in packing, for example, the fingers are constantly used in an extended position ; in the other classes of work the exact opposite is the case.

A more intensive treatment of the data (by the method of correlation) led to rather indefinite results, and the conclusion reached by Farmer is that whilst the physical type appears to play a part—though a small one—in proficiency in work, it is related to the work in question and not to any *general* characteristics making for proficiency, and that there are other and more powerful factors connected with proficiency which cannot be arrived at by physical measurement and which tend to mask the influence of physical type.

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* A careful distinction, however, is drawn between physical strength and *endurance*, and the investigation is concerned solely with the measurement of the former.

Time and Motion Study.

The object of vocational guidance and selection is the placing of the worker in employment for which he is most fitted. The natural complement to this is time and motion study, which aims at providing standard methods of training to beginners, who may have been already selected for the work on the basis of natural fitness ; vocational selection, therefore, is an antecedent to employment, time and motion study a suitable method to be applied after employment has been accepted.

As in the case of vocational selection, most of the work on time and motion study has been carried out in America, and in this country very little has yet been accomplished, but at the beginning of their existence the Board were brought into touch with one factory in which a system of motion study had been in force for some years with striking results. For a full description, the original report [**3**] must be consulted, but briefly, the system consisted of :—

(i) a complete study of the movements of a number of workers with the object of formulating a standard time for each job, such standard being fixed so as to allow of the easy performance of the job after superfluous movements have been eliminated ;

(ii) training of the operatives in the correct method of work with the aid of a time table of the movements required ;

(iii) introduction of a special method of payment, under which the price paid per piece rose automatically with the increase in output.

As a result of this system both the output and the earnings of the men (in spite of a reduction in hours) rose enormously.

Since this report was issued, two investigations, based on motion study methods (in a confectionery factory and in a metal-polishing factory respectively), have been carried out by Farmer, which indicate the vast possibilities of these methods, if properly applied, in increasing efficiency in industry.

The first of these investigations [**14,** Part II.] was carried out in certain processes in a confectionery factory. Farmer divides the work into two categories, which he designates *extensive* and *intensive* motion study. By the former is meant the arrangement of appliances and other conditions of work in such a way as to admit of unrestricted freedom to the workers' rhythm. This is an essential preliminary to successful intensive motion study, and is referred to in Section 5. By intensive motion study is meant the analysis of the workers' movements with the object of eliminating such as are wasteful or otherwise undesirable, and of adapting the performance of the work to the workers' natural rhythm.

The methods used in this investigation differ from those generally adopted and are described by Farmer as follows :—

> Time study was used to determine the time certain operations took to perform and the time relation in which one operation stood to another. It was never used to set a standard time.
>
> Motion study was used, not to determine which were the movements that took the *shortest* time to perform, but to discover those movements which when properly learnt the worker would find *easiest* to perform. The ease with which a movement could be performed was regarded as more important than the shortness of the path followed or the time taken.

For a complete grasp of the methods employed and the significance of the effects obtained, the original report must be consulted, but the results may be shortly summarised as follows :—

After extensive motion study had been applied, intensive motion study was adopted in the case of two processes, viz., sweet dipping and chocolate covering.

Sweet dipping (which is a completely manual process carried out by girls), consists in dipping a " centre " (an almond, walnut, etc.) in a basin of melted sugar with the left hand, covering it with the sugar by working it with a fork held in the right hand, and placing the finished article on the tray. On being photographed, the paths travelled over by the hands of several workers, were found in most cases to assume roughly the form of straight lines and to involve several reversals of direction. A method of doing the work was then introduced in which the hand moved entirely in curves instead of in straight lines, the continual change of direction being thus avoided and the maximum momentum being utilised for the most tiring part of the work. The advantage of the new method was indicated by the fact that it had been unconsciously adopted in modified form by three of the most proficient workers in the factory. It was found impossible to induce the older workers to change their habits and to adopt the new method, but for the younger members of the department a training class was instituted and after a short course of instruction the output increased by 27 per cent.

More striking results were obtained in another room where the process was about to be started, and after three months work the workers were on the average producing 88 per cent. more than workers of the same standing, who were adopting the old method in the original room. This difference in output may, however, have been partly due to the better conditions in the new room.

Chocolate covering by hand is similar to dipping, but differs in certain important details. The worker drops the centre into the melted chocolate with her left hand and covers it with a fork held in her right. It is a more skilled operation than dipping, and considerable practice is required to get the chocolate to adhere in the right quantity and thickness, as this is greatly affected by the temperature, and work is spoiled if the chocolate is either too cool or too warm.

Photographs showed that many of the experienced workers seemed to be using a needlessly large number of movements, and an attempt was made to introduce a " circular " method of doing the work, similar in general principles to that adopted in dipping, *i.e.*, they were told to move as far as possible in curves rather than in straight jerks and also to make as few movements as possible. No attempt was made to limit the number of movements or to enforce a rigid uniformity of method.

The new group of workers who were trained in a separate room found the method so easy that in a few months their piece rate earnings were equal to those of girls with several years' experience. When they had reached this standard they were made to join the main body of workers, many of whom became interested and began on their own account to pay attention to the number of movements they used. In this case the output of the workers who had been trained cannot be compared with that of others of the same standing, but the advantages of the new method were clearly reflected in the shorter time required to attain full proficiency.

On this part of the investigation, Farmer remarks :—

> " This example of motion study is an instance of how a principle can be laid down on which work should be done without in the least interfering with the natural rhythm of the worker. The process of covering chocolate is very intricate and cannot be hurried, since a certain amount of time must be allowed for the chocolate to cool sufficiently for it to adhere to the centre. These minute fractions of time can best be measured by each worker beating to some rhythm that she finds natural. All that can be done to improve the method by motion study is to suggest an easy method of moving the hands and to get each worker to try and do the work in as few movements as possible."

The second investigation by Farmer dealing with time and motion study [**15**] was conducted in a factory where the buffing of spoons and forks is carried on, but is applicable with the necessary modifications to all processes of grinding or polishing by means of a revolving wheel.

The chief processes studied were *outside grease dollying* and *roughing*, both of which involve manipulation of the article against a rapidly revolving wheel, and represent in inverse order successive stages through which spoons and forks pass between the press stage and the finished state.

At the beginning of the investigation there were clearly enormous differences in the movements and methods adopted by the workers, and corresponding differences in the amount of wasted energy expended on the work. Farmer, therefore, attempted to systematise the effort required by evolving a standard sequence of operations for each process, based in some degree on the methods adopted by the most efficient worker present. The slower and less efficient workers were then trained to adopt the standard method.

In the case of *outside grease dollying*, the evolving of the standard method was rendered comparatively easy by the fact that the state of the articles as received from the previous process (*roughing*) is approximately uniform. In *roughing*, however, the articles vary in regard to their surface finish, and the problem was more difficult. On this account the standard methods adopted for the two processes differed to some extent. In the case of *outside grease dollying* it consisted of a detailed scheme showing the sequence of individual operations ; in the case of *roughing* it merely indicated the maximum number of strokes demanded by each part of the article.

Similarly, the test of efficiency differed in each case. In *outside grease dollying*, efficiency was measured by the average time required to complete each article (corrected to terms of a common unit) ; in *roughing*, by the number of strokes taken and the weight of metal removed in roughing three dozen spoons of special type.

The results obtained may be summarised as follows :—

TABLE XI.—*Outside Grease Dollying.*

Worker.	Article.	Time required per article. (Seconds).		
		Original Method.	Standard Method.	*Percentage Reduction.*
C ..	Table Forks ..	43	26	*39*
D ..	,, ,, ..	44¾	33	*27*
D ..	Tea Spoons ..	24	15½	*35*
B ..	Table Forks ..	24½	22½	*8*
F* ..	,, ,, ..	70¼	27¾	*60*
G* ..	,, ,, ..	81½	31½	*61*

* Workers F and G were novices who had been at work one week, and the figures in Col. 4 represent their output after one day's training in the standard method. Their subsequent improvement is shown in the following table :—

Day of Week. (Omitting Saturday).	Percentage Relative Output.					
	1st Week.		2nd Week.		3rd Week.	
	F.	G.	F.	G.	F.	G.
Monday	46	15	74	—	140	142
Tuesday	94	43	92	—	151	133
Wednesday	33	50	125	135	—	—
Thursday	43	—	158	140	—	—
Friday	64	—	181	142	—	—
Average	*56*	*36*	*126*	*139*	*146*	*138*

(During four days G. was employed on the somewhat similar operation of roughing.)

Farmer points out that on the basis of these figures a beginner, given adequate training can become an expert dollier within a few days, but that left to herself without proper instruction she probably will never become highly skilled, and will continue all her life to waste her energies on unnecessary and unproductive movements.

TABLE XII.—*Characteristics of twelve workers roughing three dozen Baguette dessert spoons (before and after instruction).*

Worker.		Time taken (minutes).		Strokes made.		Weight removed (oz.)	
No.	Experience. (Mths).	Before instruction.	After instruction.	Before instruction.	After instruction.	Before instruction.	After instruction.
10	16	74½	69	83	69	1·6	1·6
15	10	86½	72	95	76	1·8	1·5
5	5	62½	75	54	74	1·4	1·8
21	10	128	77	119	88	2·2	1·4
25	6	154	78	165	64	1·5	1·8
6	15	68	88½	64	51	1·9	2·4
19	12	96	91½	88	88	1·2	1·8
22	9	137	99	167	98	2·2	1·8
26	6	261	99½	196	84	1·9	1·5
24	10	150	105	131	92	2·3	1·5
20	10	126	106	128	103	1·4	1·5
23	10	148	113	137	87	2·8	2·4
Average	for all	126	89	119	83	1·85	1·75

TABLE XIII.—*Record of novices roughing three dozen dessert spoons.*

Worker.	1st week.		2nd week.		3rd week.	
	Time required. (Mins.)	Strokes made.	Time required. (Mins.)	Strokes made.	Time required. (Mins.)	Strokes made.
27 ..	138	135	126	97	123¾	92
28 ..	111	116	165	138	123	99
29 ..	240	182	123	141	—	—
30 ..	138·5	121	90	109	81	82

In connection with this work, Farmer shows the effects of adjusting what might be assumed to be trivial and unimportant conditions. A worker, for example, was found to have placed the stool on which she stood too far forward, with the result that she was forced into a slightly cramped position. On the stool being moved back about three inches, she reduced the time required to rough four spoons from 14¾ to 10⅓ minutes.

Similarly the necessity of studying the individual is emphasised. One worker had acquired over a long period certain wasteful methods of work. By paying special attention to her, these were corrected one by one, and the resulting steady improvement can be seen in the following successive stages :—

TABLE XIV.—*Improvement during instruction.*

Stage.	Time taken.	Strokes made.	Weight removed.
Before instruction	148	137	2·8
1st stage	113	87	2·4
2nd ,, ...	89	71	2·4
3rd ,, ...	84	79	1·9

Finally, Farmer in this investigation makes an important contribution to the study of rhythm by the use of the wattmeter on the lines already described (p. 23). By the analysis of the charts recording the worker's action, he shows that the time required to perform a certain task (in the process concerned, namely, roughing) is a function of the number, duration, and pressure of the strokes applied by the worker; in other words, that *increase* in effort may connote *decrease* in output, owing to the interference of fatigue with the natural rhythm of the body.

Other Methods.

In addition to these special investigations, passing references to the personal factor occur elsewhere in the Board's Reports.

*Time Study.**

A detailed time study analysis of the operations involved in bobbin winding is given by Wyatt and Weston [**8,** 11]. In this the operations are distinguished as " regular " and " occasional," and the possibility is discussed of re-organisation with a view to relieving the winder herself of the latter kind and so increasing her productive capacity.

Design of Machinery and Plant.

In the same report [**8,** 9] the relation of machine design to fatigue and efficiency in the case of winding frames is discussed, and illustrations are given showing the differences in this respect between different types of frame.

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* A report by P. M. Elton, M.Sc., dealing with time study in silk-weaving has been lately placed at the disposal of the Board by Messrs. Grout & Co., Ltd., of Great Yarmouth.

Farmer, again, in his investigation in the confectionery trade shows the importance of design in two different processes. In sweet dipping, [**14,** 37] it was noticed that the small size of the trays used was one of the sources of unproductive labour, owing to their rapid emptying and the necessity of frequently replacing them by full ones. A new and larger form of tray, designed after measurement of the workers' arms and the size of the bench, was then introduced, which found great favour with the workers and brought about a decrease of the unproductive part of the work from 21 to 7·5 per cent.

Design of a different kind was studied in the process of packing assorted chocolates [**14,** 45]. Under the old system a separate box was used for each kind of chocolate, and in making the assortment the worker had to remember how many chocolates should be taken from each box. The system was then altered by increasing the number of boxes to twelve (the maximum practicable) and arranging them in such a way that the worker could make the selection according to a definite rhythm (e.g., taking one chocolate from the first four boxes, four chocolates from the fifth, one from the next four boxes, four from the tenth, etc.) The new method of packing resulted in an increase in output of 38 per cent.

Finally, Vernon [**1,** 27] points out the importance of reducing, so far as possible, the very heavy physical work of the mill men in the tinplate trade, and makes certain suggestions with a view to reducing the weight-lifting involved.

Clothing.

Another matter also alluded to by Vernon, which closely affects the comfort of the worker and the ease with which he can do his work is the clothing worn in hot and heavy occupations in the tinplate [**1,** 28] and the iron and steel trades [**5,** 96]. Instead of the heavy trousers and pants usually worn light flannel trousers are suggested, and it is also maintained that if facilities were provided at the works for changing clothing already saturated with perspiration, there would be a far less prevalence of rheumatism, a complaint to which many workers of this kind are especially liable [**5,** 99].

Seats.

Some investigation has been made by Farmer into the effects of providing seats in the metal-polishing process (*outside grease dollying*) [**15,** 10]. A special stool suitable for the work was designed, and the worker was allowed to please herself as to whether she used it or not. It was found that she generally preferred to stand all the morning and sit for the rest of the day.

Her output a minute on different articles when seated and standing was as follows :—

TABLE XV.—*Effect of Seating on Output.*

Article.	Output per minute.		*Percentage increase.*
	Standing.	Sitting.	
Coffee spoons	2·90	2·94	*1·3*
Tea spoons	2·56	2·63	*2·7*
Dessert spoons	1·70	1·76	*3·6*
Table spoons	1·28	1·58	*23·2*
Dessert forks	1·18	1·55	*31·6*
Table forks	1·16	1·25	*7·8*

Farmer points out that although the differences in speed are for the most part slight, the increased output in table spoons on a day's working is represented by one gross, and that in dessert forks by still more.

The hourly output curve showed more fluctuations when sitting than when standing, but is more buoyant, in that it frequently reaches the highest standard of the day, whereas there is a practically continuous drop in the standing output curve. The duration of the rest-pauses voluntarily taken under the two conditions was about the same (87 mins. standing and 85 mins. sitting).

Since the experiment was started other stools have been furnished and are much appreciated by the workers. The stools have the further advantage of diminishing vibration by preventing direct contact between the worker's feet and the floor.

SECTION 5.—MISCELLANEOUS POINTS.

In the case of investigations covering the wide field allotted to the Board, certain matters necessarily come to light which cannot conveniently be grouped under any of the foregoing sections, and which must therefore be considered separately.

Mechanical and Technical Efficiency.

This term is intended to cover all the factors contributing to industrial efficiency excepting the human factor. Though the investigators to the Board can as a rule lay no claim to any thorough technical knowledge of the industries investigated, the Board in considering their reports have had the assistance of representatives of the trade concerned. The matters referred to under this heading, therefore, whilst they should be regarded less as definite conclusions than as suggestions, are at least suggestions which are deserving of consideration from a technical aspect.

Vernon, in his report on the iron and steel industry, calls attention to the following means whereby output could be greatly increased :—

(*a*) Substitution of mechanical for hand-charging on blast-furnaces with an estimated increase in efficiency of 400 to 800 per cent. [**5,** 12].

(*b*) Substitution of mechanical for hand-charging on open hearth furnaces with an estimated increase in efficiency of 500 per cent. [**5,** 30].

(*c*) Substitution of hot metal for cold in charging steel furnaces with an estimated increase in efficiency of 30 per cent. [**5,** 32].

(*d*) Avoidance of intermittency in tapping of the steel furnaces whereby a more regular supply of ingots to the rolling mills would be secured [**5,** 43].

He suggests that a technical inquiry into the possibilities of the changes by a competent body of practical men is well worth consideration.

Farmer calls attention to the importance in metal-polishing of the proper use of the abrasive material used [**15,** 44].

Elton, again, in his report on silk-weaving [**9,**11] gives a method of estimating the efficiency of the loom, having regard to the differences in the class of material being woven, and advocates the current recording of the efficiencies in a special efficiency book. The numerous use to which such records could be put after collection are described. A similar suggestion is made independently by Wyatt in respect of the cotton industry [**7,** 12].

Organisation.

The interdependence of workers engaged on the same process (*team work*) or on successive processes (*routing*) has come under notice in several investigations.

Team work has been investigated by Farmer in some detail. An instance of unsuccessful team work occurred in one of the processes in metal polishing (outside grease dollying) [**15,** 15]. When the investigation was begun, two workers (A and B) were engaged in dollying spoons and forks, B doing the first operations, and then passing on the articles to A to complete. It was noticed, however, that A being the faster worker was being continually delayed through having to wait for the articles from B. They were therefore invited to work separately with the following result :—

TABLE XVI.—*Output of two dolliers working* (*a*) *together and* (*b*) *separately.*

Article.	Output per minute.		*Percentage increase.*
	A working with B.	A working alone.	
Tea spoons	1·62	2·56	*58·0*
Coffee spoons	2·06	2·90	*40·8*
Table forks	0·81	1·16	*43·2*

The above figures merely illustrate the well-known fact that the pace of a team is that of its slowest worker, but in addition the hourly output curve shows a far greater regularity for the workers separately than for the workers together. This irregularity in the combined curve is due partly to delays in the supply of articles, and partly to a tendency to discuss any peculiarity in the work of mutual interest.

In contrast with this example team-work was successfully introduced in a confectionery factory [**14**, 41], in the case of sweet-bottling, a process which entails a considerable number of small operations (placing and packing of sweets in the jars, waxing and screwing on of lids, affixing of labels and cleaning of jars. Originally, all these operations were carried out by the same worker, an arrangement which involved considerable wasted effort and caused congestion in the neighbourhood.

A method of doing the work was therefore devised under which the whole process was carried out by a team of workers, each worker doing one particular occupation, and as an additional aid a moving belt was installed to convey the jars from one worker to the next. The screwing-on of the lids being the most tiring operation, it was arranged that no girl should screw for more than half an hour. The relief given to the screwer-on afforded an opportunity for a change for each worker every half hour, an arrangement which was probably better than any arbitrary method necessary if all the operations had been equally difficult The new system resulted in an increase of 50 per cent. in output and wages, and so much floor space was saved that the room could accommodate 90 per cent. more workers than was practicable before.

Vernon also in connection with the work of the tinplate millmen [**1,** 28] directs attention to the system of "double-manning," common in America, under which the number of men running each mill is duplicated, the men working in relays and replacing one another every few minutes. Without making definite recommendations as to its general adoption here, he suggests a special investigation into the results of working where it is now in actual operation.

The importance of efficient routing (*i.e.*, of securing regular supplies of material, so as to ensure no loss of productive time on the part of the workmen or the machine), is emphasised independently and for different industries by Vernon in rolling of steel [**5,** 59]; by Wyatt and Weston in cotton-winding [**8,** 37]; by Elton in silk-weaving [**9,** 15]; and by Farmer in confectionery making [**14,** 37, 42].

Human and Mechanical Factors in Efficiency.

It has been already shown (p. 20), that the use of output as a measure of fatigue is limited by the extent to which the human factor plays a part, and that this part may vary from 100 per cent. to almost nothing. A study of the relative extent to which in each process production depends on human and mechanical efficiency is, therefore, of great importance.

An attempt to investigate this point for textile processes has been made by Wyatt [**7**] by means of the mean variations in the piece rate earnings of individuals. The results are given graphically in Fig. 11. At one end of the scale is fancy weaving, in

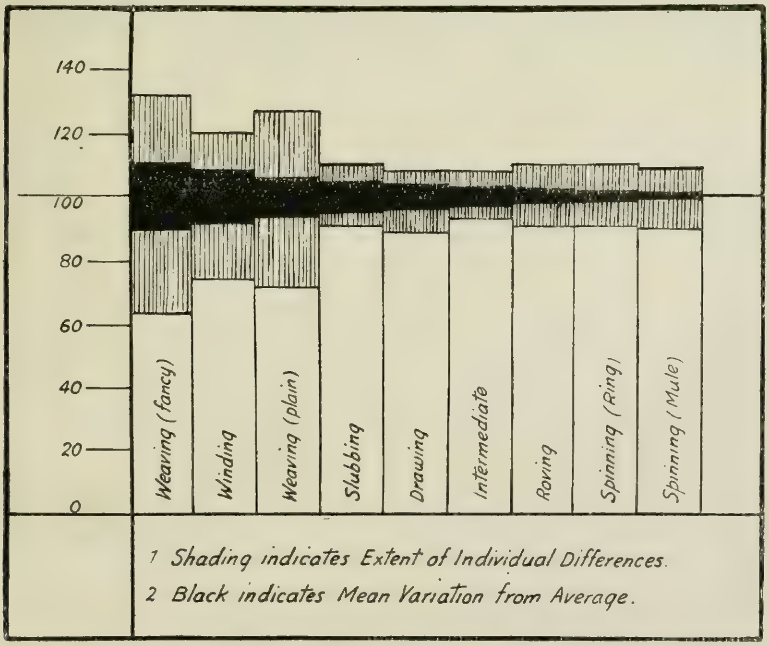

Fig. 11.—Variations in wages in different processes compared. (*The average wage is taken as* 100).

which the mean variation indicates that the human factor exercises a 10 per cent. effect on output ; at the other is the almost automatic process of mule spinning with a mean variation of only 1·9 per cent.

In many processes the optimum conditions for work (apart altogether from mechanical considerations) depend upon a certain adjustment between the human and mechanical factors. Farmer has studied this question [**15,** 55], in the case of *insiding* (one of the processes in metal-polishing), in which the insides of spoons are polished by means of a small buff fixed on a rapidly revolving spindle. As the speed of the buff is increased, the amount of human effort required per unit of output is less, but the risk of slipping off the buffs is greater. The preliminary data obtained seem to indicate that there is in fact an optimum speed for maximum output.

A rather similar question, also studied by Farmer [**15,** 39] is the proper balance between two successive processes, both having as objects the further polishing of the metal surface, in order to reduce the fatigue and unproductive work to a minimum. The processes investigated were *glazing* and *roughing*, each of which consists of holding the article against a revolving wheel, covered, however, with different abrasive material in the two cases. Farmer shows that by suitable adjustment of the application of these two processes both fatigue and the time spent unproductively is diminished, and at the same time the life of the polishing plant prolonged.

Finally, in the iron and steel industry, Vernon has classified from observation the workers engaged in different occupations according to the fatigue of the work [**5,** 75].

REFERENCES.

A.—Reports of the Board.*

[1.] **No. 1. The Influence of Hours of Work and of Ventilation on Output in Tinplate Manufacture,** by H. M. Vernon, M.D. (31 pages, with plates). [Price 6d. net, post free 7½d.]

[Compares the fatigue and output of mill-men working on shifts of four, six and eight hours, and in factories with different systems of ventilation, the data being obtained partly from existing records and partly by direct observation. The results show that for this particular work when an eight-hour shift was reduced to a four-hour shift the hourly output eventually increased by 11·5 per cent. Similarly on a six-hour shift the hourly output increased by about 10 per cent. compared with that on an eight-hour shift, corresponding to a rise of 8·3 per cent. in total weekly output. The existence of a seasonal variation in output is shown and attention is drawn to the marked effect of good ventilation on fatigue and output, efficient ventilation probably increasing the average output of an unventilated factory by 12 per cent. or more. Suggestions are also made as to suitable clothing for the work.]

[2.] **No. 2. The Output of Women Workers in relation to Hours of Work in Shell-making,** by Ethel E. Osborne, M.Sc. (23 pages). [Price 6d. net, post free 7½d.]

[Embodies the result of a small investigation based on the booking of hourly output of 43 women engaged in shell-turning during one week on two twelve-hour shifts and during one week on three eight-hour shifts, and compares the fatigue and output under the two systems.]

[3.] **No. 3. A Study of Improved Methods in an Iron Foundry,** by C. S. Myers, M.D., Sc.D., F.R.S. (8 pages). [Price 2d. net, post free 3d.]

[A short description of the methods adopted in an iron foundry with the full concurrence of the workers, the introduction of which increased the output by more than 300 per cent. for jobs that included machine work.]

[4.] **No. 4. The Incidence of Industrial Accidents upon Individuals with special reference to Multiple Accidents,** by Major Greenwood and Hilda M. Woods. (28 pages). [Price 6d. net, post free 7½d.]

[A contribution to the study of the causation of accidents, based on a statistical investigation of certain accident records kept by the Ministry of Munitions. The results indicate that accidents are very largely due to a special susceptibility inherent in the personality of the individual, so that the bulk of accidents occur amongst a limited group of individuals,

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and that the incurring of one accident is in itself of minor importance in connection with the probability of incurring a second or subsequent accident.]

[5.] **No. 5. Efficiency and Fatigue in the Iron and Steel Industry,** by H. M. VERNON, M.D. (99 pages, with plates). [Price 3s. net, post free 3s. 2d.]

[This report is based on investigations of numerous iron and steel works situated in England, Scotland and Wales, where all the workers are now on eight-hour shifts, though in certain districts they were on twelve-hour shifts until recently. It shows that as a result of the reduction of hours, the output from the open hearth steel furnaces went up 2 to 9 per cent., but that there was no change in the output from the rolling mills or the blast furnaces. The timekeeping of the blast-furnace men, however, improved, and it was found possible to reduce the number of men required to run the furnaces.

The effects of fatigue were specially seen in the blast-furnace men on Sundays, when they worked a sixteen-hour shift, their rate of charging the furnaces (by hand) being 5 to 10 per cent. less than on week-days, when they worked eight-hour shifts. Again, the rate of charging was 16 per cent. less in the summer than in the winter, and seasonal variations in the output of the heavy workers were likewise observed at the steel furnaces, the puddling furnaces and the rolling mills. Practical suggestions are made for reducing the heaviest work of all, namely, that of the steel melters when fettling (i.e., mending), their furnaces. An attempt is also made to classify occupations according to the fatigue of the work.

Sickness and mortality data relating to 24,000 iron and steel workers were tabulated for a six-year period. Men on the heaviest work experienced the most sickness, the steel melters showing 23 per cent. more than the average, the puddlers 20 per cent. more, the tinplate millmen 12 per cent. more, and the rolling mill men 8 per cent. more. The excess of sickness shown by the puddlers was due entirely to rheumatism and respiratory diseases. The steel melters showed 26 per cent. greater mortality than the average, and the blast-furnace men a higher mortality still.]

[6.] **No. 6. The Speed of Adaptation to altered Hours of Work,** by H. M. VERNON, M.D. (33 pages). [Price 1s. net, post free 1s. 1½d.]

[The report compares, by means of data derived from previous investigations and of others hitherto unpublished, the speed with which workers in different occupations adapt themselves to altered hours of work, and shows that whereas any increase in hourly output resulting from reduction of hours is gradual, in the converse case of a decrease in hourly output due to lengthening of hours the effect is immediate. A further important point, emphasising the interdependence of occupations in a factory system and indicating that reduction in hours may be fruitless unless an operation is considered in all its bearings, is brought out by the fact that in certain engineering processes the hourly output of women operatives working on short hours with the men tool-setters and labourers working on long hours was less than when the men's hours were diminished and the women's increased.]

[7.] **No. 7. Individual Differences in Output in the Cotton Industry,** by S. WYATT, M.Sc. (13 pages). [Price 6d. net, post free 7d.]

[Embodies the results of a small preliminary inquiry based on individual differences in output in various processes in the cotton industry as measured by the variations in piece rate earnings, and illustrates the extent to which in each process production depends on human, as opposed to mechanical, efficiency.]

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The various factors directly affecting efficiency in winding are discussed at length, and the operations involved in bobbin-winding are analysed into their elementary movements. Finally the relation of machine design to fatigue is illustrated.]

[9.] **No. 9. A Study of Output in Silk-Weaving during the Winter Months,** by P. M. ELTON, M.Sc. (69 pages). [Price 2s. 6d. net, post free 2s. 8d.]

[The report deals with the hourly, daily and weekly variations in production in two silk-weaving mills, making plain and fancy goods respectively, by analysis of output data collected continuously for four months from 98 looms. The various factors affecting production are discussed, and it is shown that the curve of distribution of output throughout the day has a characteristic shape. A gradual increase in output occurs from December to March, coinciding roughly with the lessened use of artificial light, under which production appears to fall about 10 per cent. as compared with daylight. Suggestions are also made for increasing efficiency, in particular the keeping of certain records.]

[10.] **No. 10. Preliminary Notes on the Boot and Shoe Industry,** by J. LOVEDAY, B.A., and S. H. MUNRO. (32 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[The above report embodies some miscellaneous points of interest arising during the initial stages of an investigation into the boot and shoe industry. It contains an historical introduction and an illustrated description of the principal processes, followed by two short sections bearing on fatigue and efficiency. The first of these deals with variations in output during the day for certain operations, and in it two inferences are drawn, first that output on Saturday is always relatively low, and secondly that the rate of production of a skilled worker is more regular and tends to fall later in the week than that of a worker whose skill is less or who is ill-suited to his work. The final section of the report is devoted to an account of an experiment with regular rest pauses in a certain pressroom, by means of which the average output from six presses was increased by 44 per cent. without the addition of new machines and with a reduction in the working hours of the individual operative.]

[11.] **No. 11. Preliminary Notes on Atmospheric Conditions in Boot and Shoe Factories,** by W. D. HAMBLY, B.Sc., and T. BEDFORD. (70 pages). [Price 3s. net, post free 3s. 2d.]

[This report which, like report No. 10, embodies part of an extensive investigation into the conditions of the industry, is concerned with the practical use of the kata-thermometer as an indicator of atmospheric conditions from a physiological aspect, and is based upon observations taken in 35 boot and shoe factories under varying conditions, and also in an aircraft doping room. It is a preliminary step towards the investigation of the relation of atmospheric conditions to fatigue and efficiency.

The report begins by enumerating the atmospheric conditions which are physiologically desirable (as enunciated by Dr. Leonard Hill). After a description of the kata-thermometer and its use, the observations in the various factories are discussed, and a comparison drawn between single storey and multi-storey buildings in regard to atmospheric conditions. The conclusions reached are summarised in the report, which is illustrated by detailed tables. In an appendix the uses of frequency curves are explained.]

[12.] **No. 12. Vocational Guidance,** by B. MUSCIO, M.A. (57 pages). [Price 1s. net, post free 1s. 1½d.]

[A critical survey of the literature on the subject with complete bibliography.]

[13.] **No. 13. A Statistical Study of Labour Turnover in Munition and other Factories,** by G. M. BROUGHTON, M.A., E. M. NEWBOLD, M.A., and E. C. ALLEN. (88 pages). [Price 3s. net, post free 3s. 2d.]

[The report deals with the labour turnover (*i.e.*, the rate of change in the working staff) between the years 1916 and 1920 in ten munition and three other factories, and is based largely on the employment records already available at the Ministry of Munitions.

It points out the advantages of periodical revision by employers of the state of labour turnover in their factories. The necessity of adopting some method of estimating labour turnover is urged, since a slight wastage may remain entirely undetected, and if unchecked will involve a serious waste of time on the part of both employers and employee. Labour turnover may also be used to indicate to some extent internal conditions in the different departments of a factory. A test is explained, which indicates whether wastage is unduly high and calls for further investigation as to the cause, and notes on factory records and record keeping are included.]

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C.—OTHER REFERENCES.

[22.] COLLIS, E. L., and GREENWOOD, M. (1921). **The Health of the Industrial Worker.** *J. & A. Churchill, London.*

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[31.] **A Comparison of an eight-hour plant and a ten-hour plant.** *U.S. Public Health Service Bulletin,* **106.**

[32.] VERNON, H. M. (1921). **Industrial Fatigue and Efficiency.** *Routledge & Sons, Ltd., London.*

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